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PROJECT SECEDE

SECEDE II ROCKET PROBE PAYLOADS

GCA Corporation

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13. ABSTRACT

A summary of the engineering design and integration of the ARPA Secede II Program rocket probe payloads which were flown in January 1971 in Eglin Air Force Base is presented. Six Terrier Tomahawk sounding rocket vehicles instrumented with a Langmuir probe, an electric field sensor, a plasma resonance instrument, a solar attitude sensor, a magnetic field sensor, and a telemetry system were flown during the program. In three of the flights, proper payload delivery was not achieved due to vehicle and despin malfunctions. One flight traversed the target successfully.

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SECEDE II ROCKET PROBE PAYLOADS

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ABSTRACT

A summary of the engineering design and integration of the ARPA Secede II Program rocket probe payloads which were flown in January 1971 in Eglin Air Force Base is presented. Six Terrier Tomahawk sounding rocket vehicles instrumented with a Langmuir probe, an electric field sensor, a plasma resonance instrument, a solar attitude sensor, a magnetic field sensor, and a telemetry system were flown during the program. In three of the flights, proper payload delivery was not achieved due to vehicle and despin malfunctions. One flight traversed the target successfully.

TABLE OF CONTENTS

SECTION I

INTRODUCTION

During January 1971, a number of barium clouds were released by night as well as a single day event off the coast of Florida at Eglin Air Force Base. Five Secede II probe payloads were launched to traverse these clouds to make in-situ measurements of certain physical parameters of the clouds.

Three scientific experiments were contained in each payload to measure electric field, electron density and electron temperature of the clouds. These experiments were also suitable to perform E and F region measurements. Terrier Tomahawk sounding rocket vehicles carried the 122 kg payload to about 240 km.

This report deals with the payload engineering design and integration effort. The performance and flight results will be presented in a separate report. The work was carried out under RADC Contract No. F30602-70-C-0288. Figure 1 shows the general configuration of the payload and Figure 2 shows a photograph of the payload.

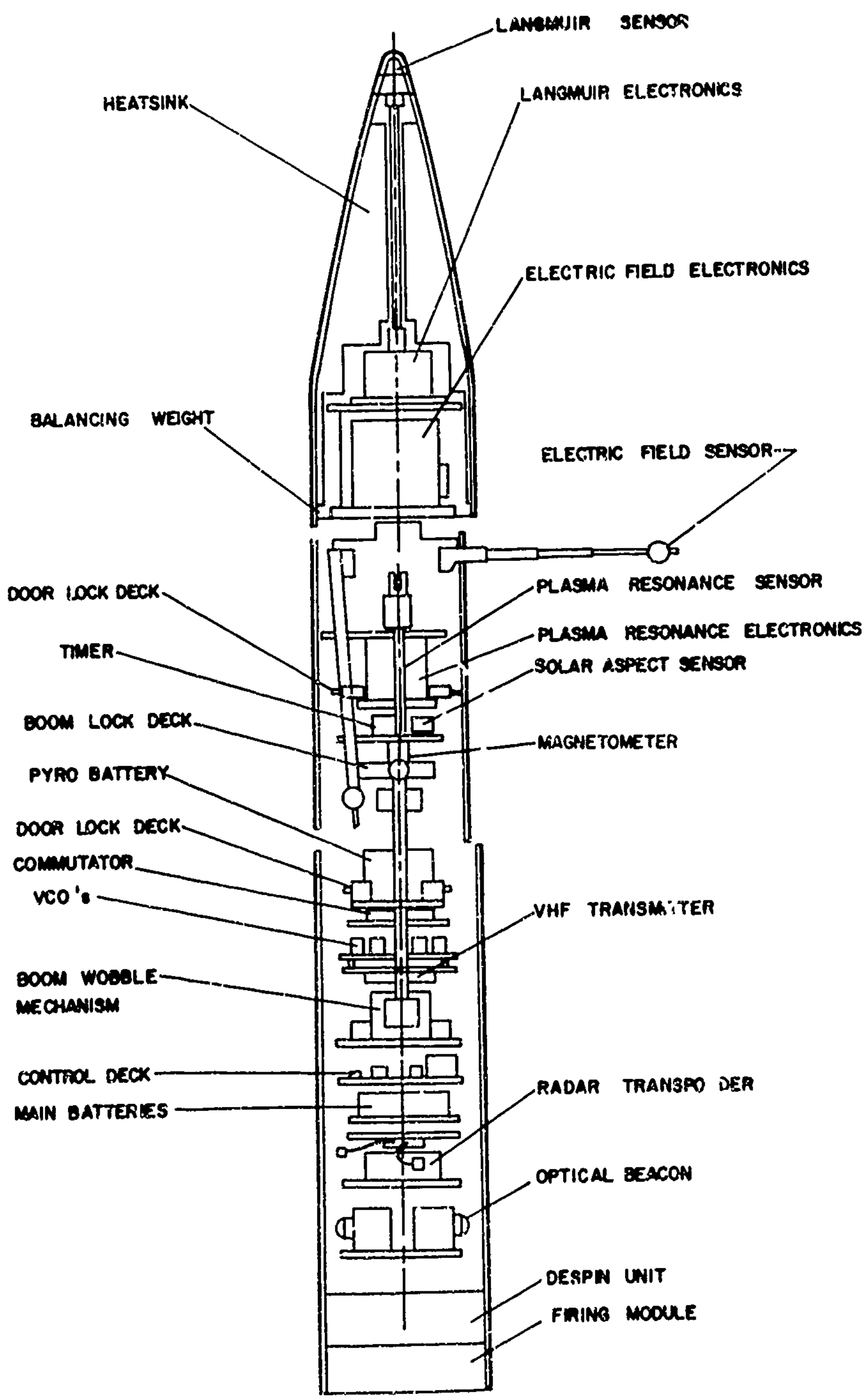


Figure 1. Secede II Flythrough probe.

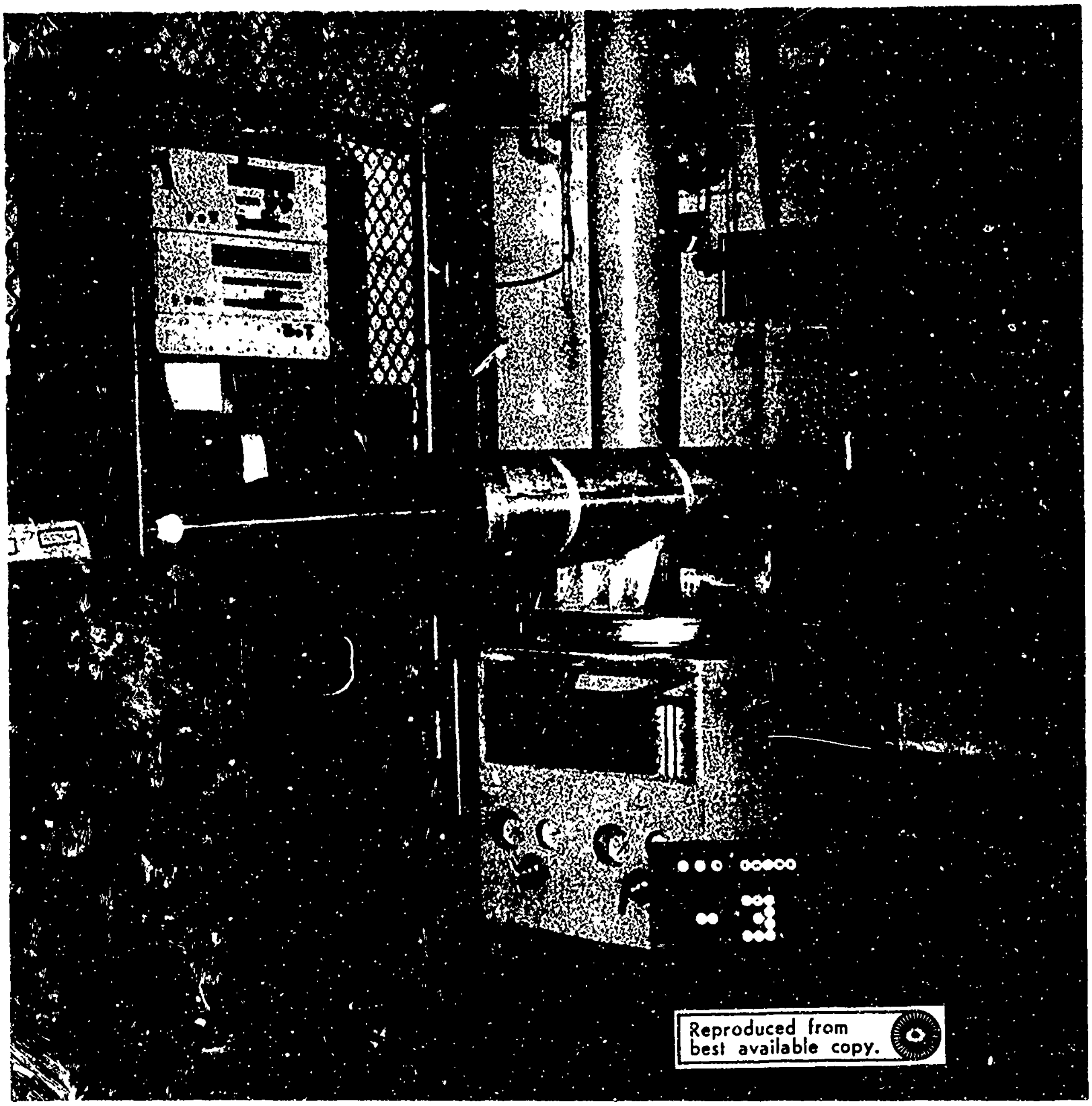


Figure 2. Secede II Flythrough probe (photograph).

SECTION II

SUMMARY

1. ORGANIZATION

The design, integration and testing phase of the flythrough probe effort of the Secede II program took place between May and November of 1970. The flight performance portion of the program was executed during January 1971 and is reported elsewhere.

The GCA Technology Division was responsible for the integration of the six payloads with the Rome Air Development Center acting as contract monitor for the Advanced Research Project Agency. The scientific experimenters were Dr. Bowhill (Aeronomy Corporation) who was the Principal Investigator, Dr. F. Mozer (University of California), whose group provided the electric field measuring instruments, Dr. K. Baker (Utah State) who provided the plasma resonance instruments and Dr. L. Smith (GCA Technology Division) who provided the Langmuir probes.

The Sandia Corporation managed the field support at Eglin Air Force Base (program control, communications, facilities, etc.); it also provided the six firing and despin systems and dynamic balancing of each payload as well as assistance in determining the mechanical rigidity of the design. Air Force Cambridge Research Laboratories supported telemetry calibration and vibration testing. The magnetic calibration was performed at the facilities of Goddard Space Flight Center.

2. PROGRAM CONDUCT

The program was started with an experimenter's meeting in May 1970, during which requirements were discussed, interface definitions were determined and a program schedule was agreed upon. The design effort was started in May and completed in July 1970. A visit was made to Sandia for consultation on aerodynamic and thermodynamic loading factors as well as on material selection for the tip and VHF antennas.

Mr. S. Meyers (Goddard Space Flight Center) visited GCA as consultant to Dr. Mozer to assist in the boom design. The procurement program was conducted from May to September 1970. All three experimenters delivered their instruments to GCA Corporation in August and September. The fabrication of parts was commenced in July and completed in September. Extensive testing of the deployment of the booms occurred in September. The assembly of the payloads took place in September and October. Each payload was subjected to a vibration test and had its telemetry system adjusted and tested in October. The orientation of the optical axis of the solar aspect sensor in reference to the two boom sets was also determined in October.

In the early part of November the payloads were forwarded to Goddard Space Flight Center, where the magnetic calibration was performed and sent to Sandia for the dynamic balancing to take place. At Sandia a bend test was also performed on one payload, confirming the soundness of the design. All the batteries were removed from five of the payloads and they, as well as one of the payloads, were returned to GCA. The one payload was subsequently fully prepared for launch check-out (which was to take place shortly after arrival of the field services team at Eglin in January). All payloads were forwarded to Eglin in December.

3. TECHNICAL DESCRIPTION

The subject sounding rocket payloads constituted the flythrough probe experiment for Secede II. The payload was propelled by a Terrier-Tomahawk motor combination and was to perform measurements of certain characteristics of barium clouds while traversing these clouds. The payload was to be tracked by radar and optical telescope; it was provided with suitable active C band beacons for both these tracking methods.

Each probe consisted of a firing and despin module and the scientific section of the payload. The firing module operated the various functions of the rocket motors and the despin module, utilizing a yo-yo design was to bring the spin rate from 9 rps to 3.5 rps to facilitate proper deployment of the electric field booms and the plasma resonance antenna. The scientific payload section consisted of a 190 cm long, 23 cm diameter, 3/8 wall thickness aluminum cylinder, a 66 cm long, 23 cm base diameter stainless ogive nose cone and an internal rack structure. The firing-despin module, cylinder and nose cone were attached to each other via radax joints (to enhance the stiffness of the structure). The total weight of the payload was 122 kg. The material for the VHF antennas was stainless steel and the material for the conical tip (which also acted as the sensor for the Langmuir probe) was tantalum. The various experiment and support assemblies are all placed on individual "decks" and attached to an internal rack structure consisting of 4 struts, which run over the entire length of the cylindrical section of the scientific section of the payload (from here on referred to as the "payload"). One of these struts contains all the wiring connecting the various deck assemblies to each other. The layout of the deck sequence was determined by the configuration of the booms and the probe, and by the fact that the Langmuir probe experiment needs to be closest to the tip of the payload and also by other criteria such as the commutator assembly being close to the prime experiments, the VCO assembly being close to the transmitter, etc.

The buildup is now executed as follows (also refer to Figure 1): (1) on the lowest deck is mounted the optical beacon, including its own batteries, (2) the radar transponder, (3) the antenna assemblies for the radar transponder and the UHF transmitter, (4) the main batteries, (5) the control deck, (6) the lower boom assembly, (7) the VHF transmitter,

(8) the VCO assembly, (9) the commutator, (10) the lower door lock assembly, (11) the magnetometer and pyro battery assembly, (12) the boom lock assembly, (13) the timer and solar aspect assembly, (14) the upper door lock assembly, (15) the plasma resonance assembly, (16) the upper boom assembly, and (17) the electric field measurement electronics box and the Langmuir electronics box.

Each payload was provided with an optical beacon manufactured by the Space Data Corporation in order to be able to determine accurately the point of penetration of the probe in the cloud. The beacon consisted of three synchronously flashing H88 xenon flash lamps, which protruded the payload shell just above the despin module. The lamps were protected against aerodynamic heating by a shroud.

The radar transponder was supplied by Vega (35 watt), having a calculated range of 240 km. The antennas for the transponder were the stub type (made of tungsten) and for the VHF transmitter were 1/4 wave type (and made of inconel); both types were supplied by Sandia. The batteries were manufactured by Yardney and yielded a nominal 28 volts having a capacity of 5 amp hours.

The control deck contained the relays that switch the various functions in the payload (external-internal power, door eject command, and boom deploy command, etc.); it also included the barometric switches, which arm the relays for the pyro technic devices and the umbilical receptacle. The lower boom assembly consisted of two triple segmented telescoping fiberglass tubes, each 1.5" long with a 4.5 cm diameter sphere at its end and a pivot and link system which was attached directly to the struts and which provided the pivots for the two booms. The booms were linked to each other such that they will move synchronously. This unit was also provided with a wobble assembly, which would move the two booms up and down through a 20° angle every 60 seconds.

The VHF transmitter was manufactured by Conic (3.5 watt) and the electronic commutator by Vector (75 pulses per second, 30 pulses per cycle). The lower door lock assembly held the two doors (for the lower boom and the plasma resonance antenna) in place via an anchor and shear pin. The pin was broken (and the doors released) utilizing a gun powder type gas cartridge (made by Holex). The magnetometer was obtained from Schonstedt. The boom lock assembly held the four booms and the plasma resonance antenna in place and would upon command, release first the booms by cutting a screw with an explosive type guillotine cutter and then, similarly, the antenna. The time was of the mechanical (cam and switch) type.

The GCA solar aspect sensor was included in the payload together with the magnetic aspect sensor to enable the attitude of the payload to be determined. The solar aspect sensor measures the angle between the spin axis of the rocket and the direction of the sun. The basis of the operation is the time interval between two pulses generated by an optical system. The output signals are compatible with the University of Calif-

ornia's signal processing systems. It is also possible to determine the angle between the spin axis of the rocket and the longitudinal axis of the payload (normal analysis procedure assumes these to coincide). The aspect sensor accuracy is typically 0.3 degrees and has a repeatability to within 0.1 degrees. The sensor was exposed to the environment through the same door opening through which one of the lower booms swing out. The upper door lock assembly serves the same function as the lower one, but for the upper doors plus one of the lower doors. (This door because of its extended length was deemed to have to be attached at two places.) The antenna of the plasma resonance instrument, being 1 meter long and not allowed to be folded or telescoped required one of the lower doors to be 1.10 meters long.

The plasma resonance probe technique involved sweeping the frequency of a low level RF signal applied to a dipole antenna and measuring the parallel and series resonance frequencies. An RF sweep generator produces a 1 volt signal that is swept in frequency from 10 to 0.1 MHz at a rate of 16 Hz. This signal is applied as a balanced voltage to a 6 mm diameter 1 meter long hollow antenna. The skin of the payload functions as the return electrode for the antenna current. The antenna resonances are sensed by monitoring the phase angle between the antenna current and voltage. At the instant the phase angle passes through zero the phase detector provides a trigger pulse causing the oscillator to pause in its frequency shift and allowing a frequency counter to determine that frequency. The logic circuitry on successive sweeps alternately causes the parallel and then the series resonance frequency to be read out by the counter. This gives 8 complete samples per second of each frequency. The output of the counter is encoded in a PCM format along with additional required information such as an IRIG frame identification word. The upper boom assembly was identical in configuration to the lower boom assembly except for the fact that the deployed booms were not movable and an electron density sensor was attached to one of the booms.

The electric field instrument was designed to measure the electric field potential of the ambient plasma with an accuracy of 1mV/m. This is achieved by utilizing two pairs of spheres, which are mounted orthogonally with respect to each other. Each pair was mounted on the booms described above, which after deployment extend perpendicular from the shell of the payload. The spheres are made from 2.5 mm thick vitreous carbon and are electrically connected to the electronics circuitry via the inner conductor of a coaxial cable. A calibration mode for the measurement was provided during the moving mode of the lower boom which caused a change in the distance between the two pairs of spheres.

The Langmuir probe was designed to measure electron density and electron temperature of the ambient plasma. The temperature was measured by sweeping the electrode from -1.35V to 4.05V in a duration of 50 m sec. Analysis of the current-voltage characteristic by Langmuir probe theory gives electron temperature. The probe was swept at intervals of 500 m sec.

In the intervening period the potential of the electrode was held constant at 4.05V. This allows determination of the electron density profile with good time, and hence, height, resolution. The electric field electronics and the Langmuir probe package were installed in the nose cone and special measures were taken to negotiate the radiant heatflux from the skin. This was accomplished with a radiative heat shield and a massive heatsink. This served the dual purpose of providing a means to achieve a more forward located center of gravity of the payload.

SECTION III

DESIGN CONSIDERATIONS

A major design constraint was the fact that the payload would be propelled by a high performance rocket motor combination (the Terrier - Tomahawk), producing a substantial heat load and high mechanical stresses. This constraint became even more pronounced given the fact that the payload would be rather extended in length (due to the large number of subsystems) and would require long slotted openings (due to the requirement that the plasma resonance antenna be of a one-piece construction.

1. HEATLOAD

The required operating time of the payload being rather brief (on the order of 2.5 minutes after second stage burnout), it was decided to negotiate the heatflux by storing the heat energy in heat sinks and provide a minimum conductance between the heat sinks and the equipment. The entire equipment rack structure (except for the electric field measurement electronic box) was enclosed by these heat sinks, consisting of the cylindrical section of the payload shell (being a 3/8" aluminum wall) and a 17.7 kg cavitated aluminum weight atop the cylindrical section enclosing the topmost equipment. The electric field measurement electronics box, although being located close to the top of the equipment rack and protruding in the nose cone area, could not be encased by a heatsink due to to the small amount of space between this unit and the skin. Instead, it was protected by a radiative heat shield consisting of highly reflective aluminum foil. The equipment rack was attached to the payload shell in five planes: the bottom deck was hard mounted to the shell and at four other places the rack was attached to the shell, but such that it was constrained only in the lateral plane. One of the payloads was instrumented with thermistors in order to determine the actual temperature rise in the following places: the nose cone skin at 40 cm below the tip (1/2 the nose cone length) at the Langmuir probe deck, the cylindrical skin at about 1/3 of the payload length from the tip and at the solar sensor-timer deck which is located about 1/3 of the payload length from the tip.

After consultation with Sandia personnel it was dediced that Inconel would be a satisfactory material for the VHF antennas from a heat load point of view, given the facts that the total payload weight would be well in excess of 97 kg and that the antennas were to be swept back, parallel to the rocket longitudinal axis. With reference to the tip given the facts of the particular heat load and the tip being thermally insulated from the rest of the nose cone (see below), a temperature rise close to 1100°C was anticipated and this was considered to be too marginal for a steel base material. Therefore, tantalum (m.p. 2990°C) was selected as the material for the tip. Likewise, aluminum was considered to be too marginal for the nose cone and 304 stainless was selected for this item.

2. MECHANICAL STRESSES

All sub-systems were installed on decks. These decks were supported by four struts which ran the entire length of the cylindrical section of the payload and three of which measured 6 x 29 mm^2 in cross-section and the fourth one of which was a 10 x 75 x 3.5 mm channel. The shell was to be provided with two pairs of long slots which, moreover, were partially overlapping (longitudinal wise) and this fact as well as the matter of the lengths of both the shell and the rack structure (190 cm) yielded a rather large slenderness factor. In order to bring that quantity down, the rack and the shell were interconnected at five places along the length of the rack and shell. Due to the different anticipated heating rates of the shell and the rack structure, only one of these interconnectors was rigid, whereas the other four were longitudinally sliding. Moreover, in order to regain some of the moment of inertia of the cylindrical cross-section of the shell which was lost due to incorporating the four slotted openings, the cylinder sectors were braced to each other at three places.

3. GENERAL

The arrangement of the various sub-systems was determined by the usual design parameters: optimum layout considering the electrical inter-wiring and topological requirements as to location of booms, antennas, viewing ports, also taking in account the ease of accessibility and assembly. At the experimenter's meeting it was determined to provide each payload with three synchronously flashing lights (the optical beacon), rather than four as was originally proposed and to locate these at the very bottom of the payload (in order to minimize any interference by the lights with the electric field experiment).

SECTION IV

CONSTRUCTION

The general layout is first described below, followed by a discussion of each of the sub-systems.

1. GENERAL LAYOUT

Sandia had required the joints to be of the radax type and the order was such that the experiment section of the payload was to mate to the female part of the joint, thus the bottom of the payload had to incorporate the male part of the joint. It was decided to machine the joints as an integral part of the skin, leaving a 20 cm dia. opening at the bottom and the top having the female part of the joint a 21 cm dia. opening at the top of the cylindrical shell section. In order to utilize the circular cross-section fully, it was decided to build the rack to an outside diameter of 20.8 cm and lower the rack assembly into the shell (as opposed to the regular procedure where the shell is lowered over the rack). The bottom deck of the rack structure was attached to the shell; it held two of the component assemblies of the optical beacon as well as the wiring rail and two of the rack struts. The third strut did not go below the second deck, otherwise it would have interfered with the optical beacon. Instead, the second deck was supported by two additional posts.

The order in which the sub-system was installed is as listed in Section III. In order to minimize the number of slots in the shell, the plasma resonance antenna was deployed through the same slot as one of the lower electric field booms. Likewise, the solar aspect sensor was exposed to the environment through the same slot through which the other lower boom was deployed.

2. PAYLOAD SHELL

The payload shell consisted of two parts: the cylindrical section made of A6061-T6, 23 cm outside diameter x 9.5 mm wall thickness and 190 cm long and the nose cone, being an ogive configuration of 304 stainless, 23 cm outside diameter x 1.5 mm wall thickness and 66 cm long. The nose tip was 4 cm long, made of tantalum and separated from the stainless steel section by a 4 cm long alumina insulator. The tip served as the collector for the Langmuir probe and had, therefore, to be electrically insulated from the payload shell; its area was 7 cm^2. The boom deployment slots were each covered by a door. Each door was ejected by causing it to hinge along the leading edge so that no rotational momentum would be transferred from the spinning payload into the receeding doors. The doors were held on by anchors which are detached from the payload frame by shearing a pin utilizing an explosive charge. Three braces, 6 mm thick aluminum discs spaced 23 cm apart tied the shell sectors together where the slots were located.

3. RACK STRUCTURE

The rack structure consisted of three 6 mm x 29 mm x 191 cm long A6061-T6 bars, a 10 x 75 x 3.5 mm channel and 15 A6061-T6 decks each 6 mm thick. The channel, in addition to functioning as a structural member, also served as a wiring conduit. The wiring was secured to the channel with Eccofoam. The rack was attached to the shell via the bottom deck (hard mounted), the three brackets (longitudinally sliding interface) and four screws at the very top of the cylindrical section of the shell (the screws being fastened to and protruding the shell and engaging slots in the rack struts again yielding a sliding interface). The deck to which the Langmuir probe electronics box was mounted was not attached directly to the rack struts, as they could not protrude into the nose cone area due to interference of the radax joint, but via the electric field measurement electronics box.

4. OPTICAL BEACON

The beacon consisted of three synchronously flashing H88 xenon flash lamps, which protruded the payload shell just above the despin module. The lamps were protected against aerodynamic heating by a shroud. Each lamp was powered by a capacitor, which was charged by a power supply yielding an output of 2.5 joules per flash. The three capacitors were triggered to discharge from a central trigger circuit at a rate of 1 discharge per 1.7 sec. In case of malfunction of this circuit, each capacitor would be triggered by its own trigger circuit at a slightly slower rate. The lamps would then be flashing in a non-synchronous mode. Due to darkening of the lampglass during operation, the lifetime at rated light intensity output was 12 minutes. The beacon consisted of five sub-assemblies: the battery box containing 19 Yardney HR3 silver cells, the power supply unit and three lamp-capacitor units. The former two were attached to the bottom deck and the lamp units were attached to the shell. All five sub-assemblies were assembled after the rack was installed in the shell through a hold in the bottom deck.

5. RADAR TRANSPONDER

The radar transponder was manufactured by Vega, Model No. 207C. It had a calculated range of 240 km.

6. RF ANTENNAS

The RF antennas were manufactured by Sandia. The two radar transponder antennas were of the stubby type and were made of tungsten. The two VHF antennas were of the 1/4 wave type, made of Inconel and they were swept back such that 2/3 of their length was parallel to the rocket longitudinal axis.

7. MAIN BATTERIES

The main battery assembly provided power for the entire payload except for the optical beacon and the explosive devices. The assembly consisted of 19 Yardney HR5 silver cells yielding 5 ampere hours at a nominal 28 volt DC. The batteries were contained in an aluminum casting.

8. CONTROL DECK

The control deck contained the relays that switched the various functions in the payload (external to internal power, wobble motor pulse delay circuit, door eject command, boom deployment command, etc.); it also included two barometric switches (threshold at 13 km, made by Precision Sensor Part No. A37C-23) which arm the relays for the pyrotechnic devices.

9. BOOM ASSEMBLIES

Each boom assembly (lower and upper) consisted of an aluminum casting which was attached directly to the struts and which provided the pivots for the two booms. The booms were linked to each other such that they would deploy synchronously. The casting of the lower assembly also held a wobble assembly, which consisted of an ITT Model MA11A1114 actuator driving an eccentric and a connecting rod. A cam would "self-hold" a switch-in-series with the motor for one cycle. To start the cycle a command pulse of 1 second duration generated by the electric field electronics circuitry would override the series switch. This pulse was generated once every 58 seconds. The eccentric was normally in the down position. When the booms had been deployed, their linkage was made to lock onto the connecting rod, so that the linkage and the booms would follow the eccentric motion. Please note that the linkage was only locked to the connecting rod when the booms had been fully deployed, i.e., when the actuator would inadvertently be started with the booms in the folded position, the motion of the eccentric would not be transferred to the booms (the actuator would still stop automatically after one full cycle).

Each boom consisted of three sections which telescoped into each other. These were made of glass fiber phenolic tubing. In the folded position the three segments were locked internally so that they would not extend prematurely. The deployment of the booms as well as the extension of the boom segments was accomplished by the centrifugal force which would be generated by the spinning rocket. In addition a spring was incorporated to assist in starting the deployment. Upon initial deployment, the segments were kept locked and each pair of booms was unlocked simultaneously 10^{o} prior to reaching full deployment. A potentiometer was installed at one of the pivots of each unit to indicate deployment during the flight. At the end of each boom a vitrous carbon sphere of 4.5 cm diameter was attached. The top boom assembly held two ballast weights of 2.3 kg each.

10. TRANSMITTER-VCO ASSEMBLY

The VHF transmitter was made by Conic, Model CTM-402, radiating 3.5 watt. The transmitter was driven by 9 VCO's, made by IED, Model C50 220-1.

11. THE CUMMUTATOR

The commutator was an electronic type (the noise interference of a mechanical type was unacceptable to the electric field experiment). It had 30 pulses per cycle and operated at a rate of 75 pulses per second. It was made by Vector, Model CSV-100.

12. DOOR LOCK ASSEMBLIES

Each door lock assembly (lower and upper was installed on a shell brace. The braces being attached directly to the skin, ensuring that the door locks would "travel" with the extension (due to a rise in temperature) of the skin. Each door lock assembly consisted of one Holex Model 6203 pressure cartridge, a piston block, two pistons (three pistons in case of the upper door lock), and anchors which were attached to the piston block via a shear pin. Three doors were each attached to an anchor, whereas the fourth door was attached to two anchors (one at the upper and one at the lower door lock assembly). Firing the cartridge would propel the piston, which then would cut the shear pins so that the anchors and the doors were ejected. The pistons were trapped, so that no pressure loss would occur even when one piston would be ahead of the other in cutting the shear pin.

13. MAGNETOMETER AND PYRO BATTERY ASSEMBLY

The magnetometer was installed to determine the position of the electric field spheres and of the plasma resonance probe with respect to the earth's magnetic field lines. The magnetometer was to serve in addition, a secondary purpose in providing a quick look record of the spin history of the payload-indicating the times at which the payload would be despun and the booms would be deployed. The magnetometer selected was a Schonstedt Model RAM-5C. The pyro battery assembly consisted of 18 Yardney Model HR01 cells, providing power to ignite the various pyrotechnic devices.

14. BOOM LOCK ASSEMBLY

The boom lock assembly clamped the four booms in the folded position with a latch. The latch was locked by a screw which was to be cut by a Holex model 2801 guillotine cutter upon command; the latch would thence be unlocked by a spring, releasing the four booms simultaneously. The plasma resonance probe was locked and released in a similar way.

15. SOLAR ASPECT SENSOR AND TIMER ASSEMBLY

The GCA solar aspect sensor was included in the payload to enable the attitude of the payload with respect to the solar vector to be determined. The solar aspect sensor measures the angle between the spin axis of the rocket and the direction of the sun. The basis of the operation is the time interval between two pulses generated by an optical system.

The assembly is contained within a rectangular aluminum housing. The overall size is 1 1/2" by 1 3/8" x 2". The instrument has three main sub-assemblies: (1) the front and rear aperture plates with self-locating spacers, (2) the solar cell, (3) the switching circuit. The aspect sensor for Secede had been modified by changing the aperture to generate output signals which are compatible with the University of California's signal processing systems. The modification would also make it possible to determine the angle between the spin axis of the rocket and the longitudinal axis of the payload (normal analysis procedure assumes these coincide). The aspect sensor accuracy on previous payloads has been 0.3 degrees in the worst case (aspect angles approaching 0 degrees), and has a repeatability to within 0.1 degrees. The aspect sensor power requirements are +30V at 12.0 ma. The timer was a Raymond model 1060-3G-180T; it incorporates a gravity actuated switch which is operated by the lift-off acceleration force and it commanded the doors to be ejected at 5 seconds after despin, the booms to be deployed at 10 seconds a.d. and the plasma resonance probe to be deployed at 15 seconds a.d.

16. PLASMA RESONANCE INSTRUMENT

The plasma resonance instrument consisted of the electronics box and the antenna. The electronics circuit is described in Section III. The antenna, a 6 mm x 1 m long stainless steel tube, was mounted on a pivot and provided with a counter weight, such that the center of gravity of the antenna assembly was located in the pivot axis. Thus, the roll movement of inertia of the payload would only negligibly be altered upon deployment of the antenna. The antenna upon release from the antenna lock would be deployed by the force of a spring. A potentiometer on the pivot would monitor the deployment during flight.

17. ELECTRIC FIELD MEASUREMENT

The electric field instrument was installed on the top deck. The sensor spheres at the end of the four booms were electrically connected to the circuitry via coaxial cables. The instrument is described in Section III.

18. LANGMUIR PROBE

The Langmuir probe electronics box was installed on top of the electric field base. The circuitry was contained within a cylindrical unit

13 cm in diameter and 18 cm in height. The unit was filled with Eccofoam potting compound. Connection with the nose tip sensor was made via a rod to a special connector which extended 8 cm above the electronics package. The probe tip area was 7 cm^2 and the range of the electrometer extended to accommodate the range of electron densities (3×10^3 to 3×10^7 cm^{-3}). This modification allowed a change in the instrument sensitivity with a minimum of modification to its electronics. The instrument contained six sub-assemblies: (1) DC/DC converter (-30V, 3 watts output), (2) a 5-second calibration circuit, (3) probe timing function generator, (4) log and linear electrometers, (5) ramp generator, (6) floating battery pack.

The DC/DC converter (TEC Model N9567-106) provided negative voltages to decks requiring negative biasing. The converter required +25 to +35V input and had a rated efficiency of 46 percent.

The calibration circuit was designed to generate in-flight instrumentation check. The circuit was to be activated by the 13 km baroswitch closure. At this point 5 seconds of calibration data would be generated. During the second phase of the flight (re-entry) the 13 km baroswitch would be disengaged and an additional 5 seconds of calibration data would be generated.

The probe timer being a system clock, also generated the required pulses for both the DC and sweep modes of operation.

The logarithmic electrometer exhibited a dynamic range of 6 decades. The output voltage for zero input current was approximately 0 volts. Full scale deflection (5 volts) represented an input current of 10^{-3} amp. The linear electrometer was designed such that 5 volts output would represent 10^{-5} amp input current.

The ramp generator received its power from the floating battery pack. The sweep ranges were determined by selecting the proper resistor value in the output stage of the ramp circuit.

19. HEAT SINK

The heatsink was attached to and supported by the cylindrical part of the shell via four 15 cm long struts. It encased the Langmuir probe electronics base, but extended beyond it so that its additional function viz that of ballast would be enhanced. The heatsink was made of an aluminum casting.

SECTION V

TEST PROGRAM

The environmental qualification philosophy for the program did not require each system to be qualified separately as each experimenter had qualified their design on previous rocket programs. Moreover, each fully integrated payload was to be tested and thusly, all sub-systems would be qualified in the subject flight configuration.

1. OPTICAL BEACON

Because of the concern with the lamps, one prototype unit was subjected to the following environmental tests:

Vibration: The unit was to operate while being exposed to a random vibration spectrum of 8 g rms between 5 Hz and 2000 Hz for a period of 4 minutes in the direction of the longitudinal rocket axis.

Shock: The unit was subjected to two shocks of 5.5 g's each, 11 msec duration half sine wave.

The prototype passed these tests satisfactorily.

2. BOOM DEPLOYMENT TESTING

The design of the boom deployment and extension was extensively tested on a spin table. The deployment (the folding out of the stowed position by the booms) operated satisfactorily at the first and all subsequent test runs. The extension of the booms (the telescoping out of the locked position by the boom segments) initially was not reliable; one or two of the four booms would not extend fully. After the cause of this (see Section VII) was corrected, the boom extension occurred reliably. Likewise, the plasma resonance antenna deployment was tested and it operated satisfactorily at all test runs.

As the deployment and extension were achieved by centrifugal force, there would be a minimum required spin rate above which these actions would take place reliably. During the testing it was established that for reliable deployment a spin rate of 0.8 rps was sufficient and that for reliable extension a minimum spin rate of 1.9 rps was required. It was also established that at spin rates higher than 4.2 rps the booms could be damaged (i.e., the spheres were liable to get detached from the booms). As the spin rate (after despin from the post second stage burnout spin rate) was specified to be 3.5 ± 0.5 rps, the boom design was judged as acceptable for the mission. It was also noted that at spin rates above 4.5 rps, the plasma resonance antenna would on occasion break off (the antenna did not require a minimum spin rate as its deployment was accomplished by the force of a spring).

3. TELEMETRY TESTING

Each payload was operated in the flight mode: on internal power and radiating to a ground station. All the VCO's were adjusted during these tests and it was established that each payload was operating satisfactorily.

4. VIBRATION TESTING

Each payload, with the internal power switched on and the optical beacon operating on a spot base was exposed to the following vibration test: a sinusoidal sweep from 2 to 2000 to 2 Hz at a rate of 1 octave per minute, with the excitation input in the longitudinal direction at the following levels:

Frequency (Hz)	Level (g)
2-500	1
500-700	2
700-1500	2.5
1500-2000	2

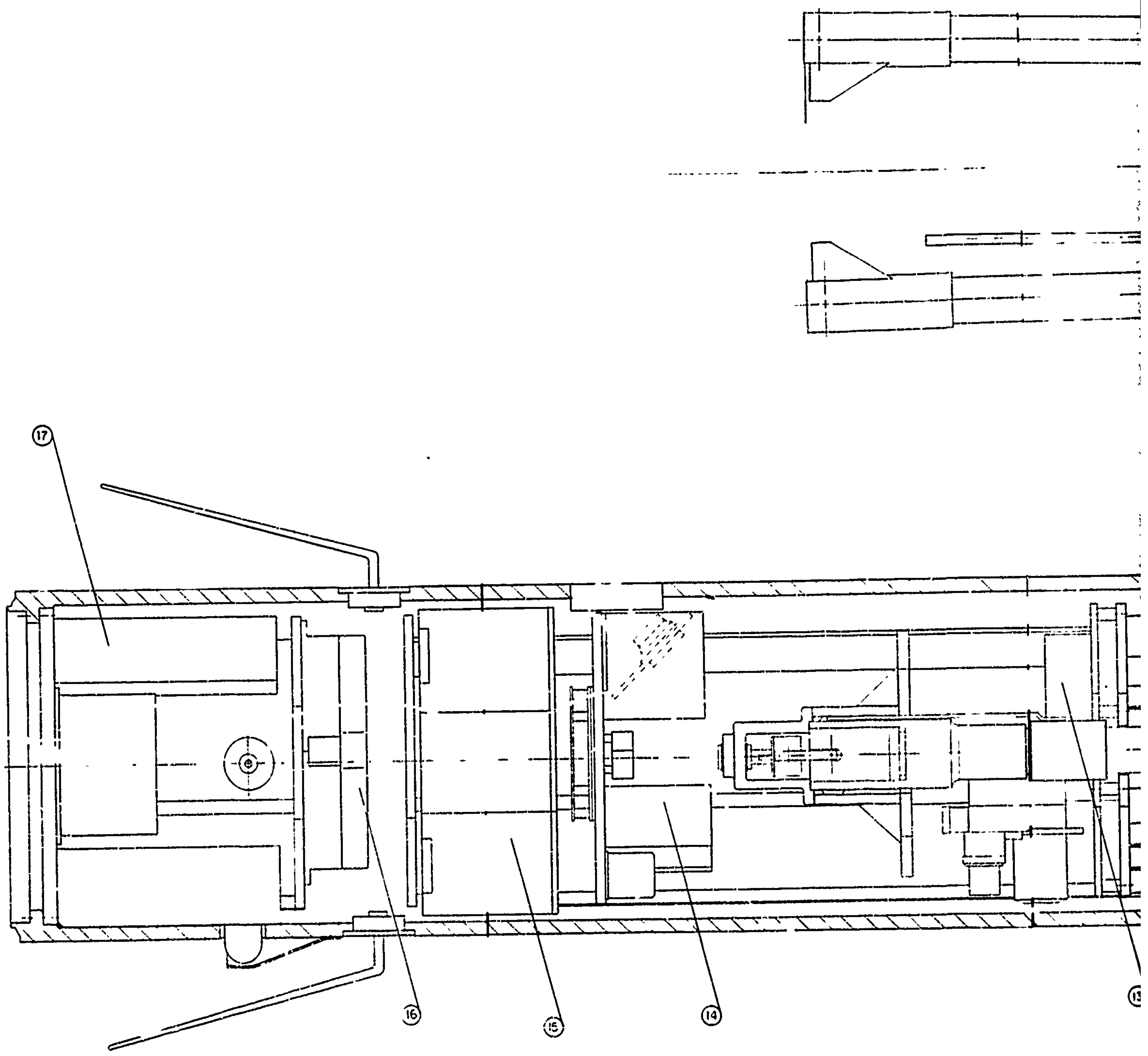
During each test the payload was instrumented with an accelerometer on the plasma resonance deck (about 1/3 of the payload length from the tip) to establish resonance frequencies and multiplication factors. It was noted that the resonant frequencies typically were at 60 Hz (multiplication factor of 1.5), 180 Hz (mf of 5), at 280 Hz (mf of 4.5), at 590 Hz (mf of 1.5), at 122 Hz(mf of 1) and at 1800 Hz (mf of 1).

SECTION VI

SALIENT DATA

In this section the salient data of the subject payload are compiled.

A



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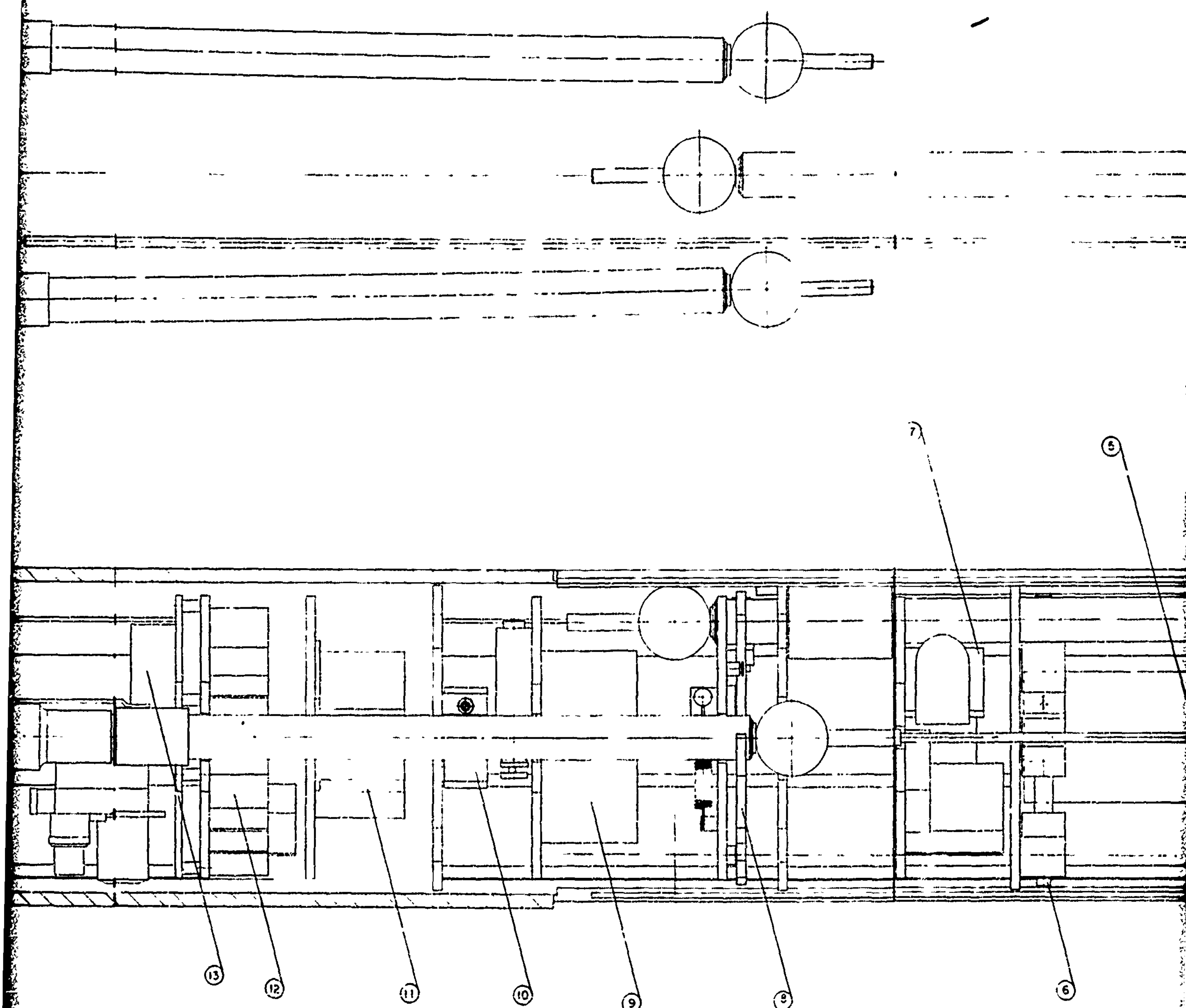
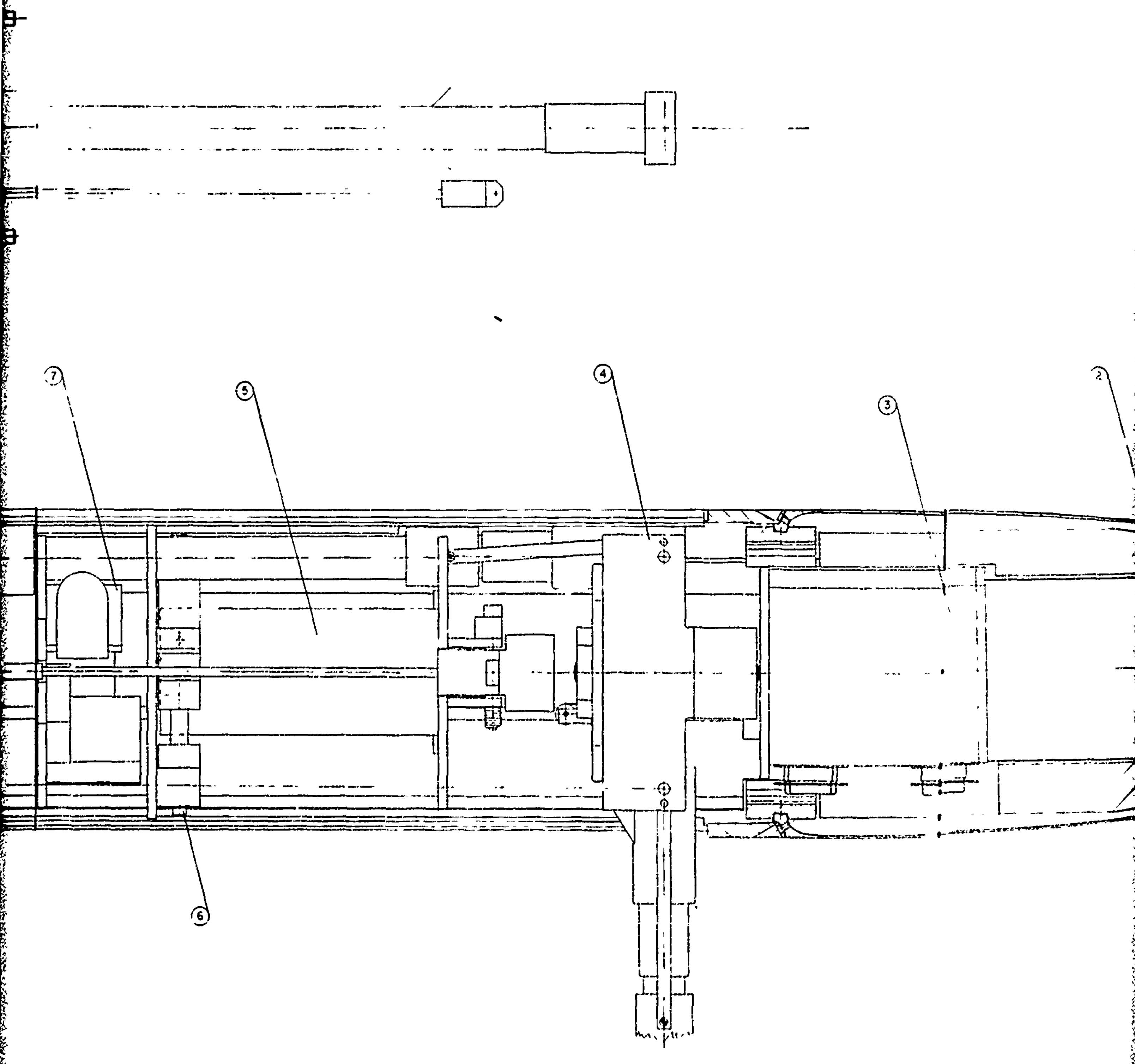



7
5
4
3
2
6

D

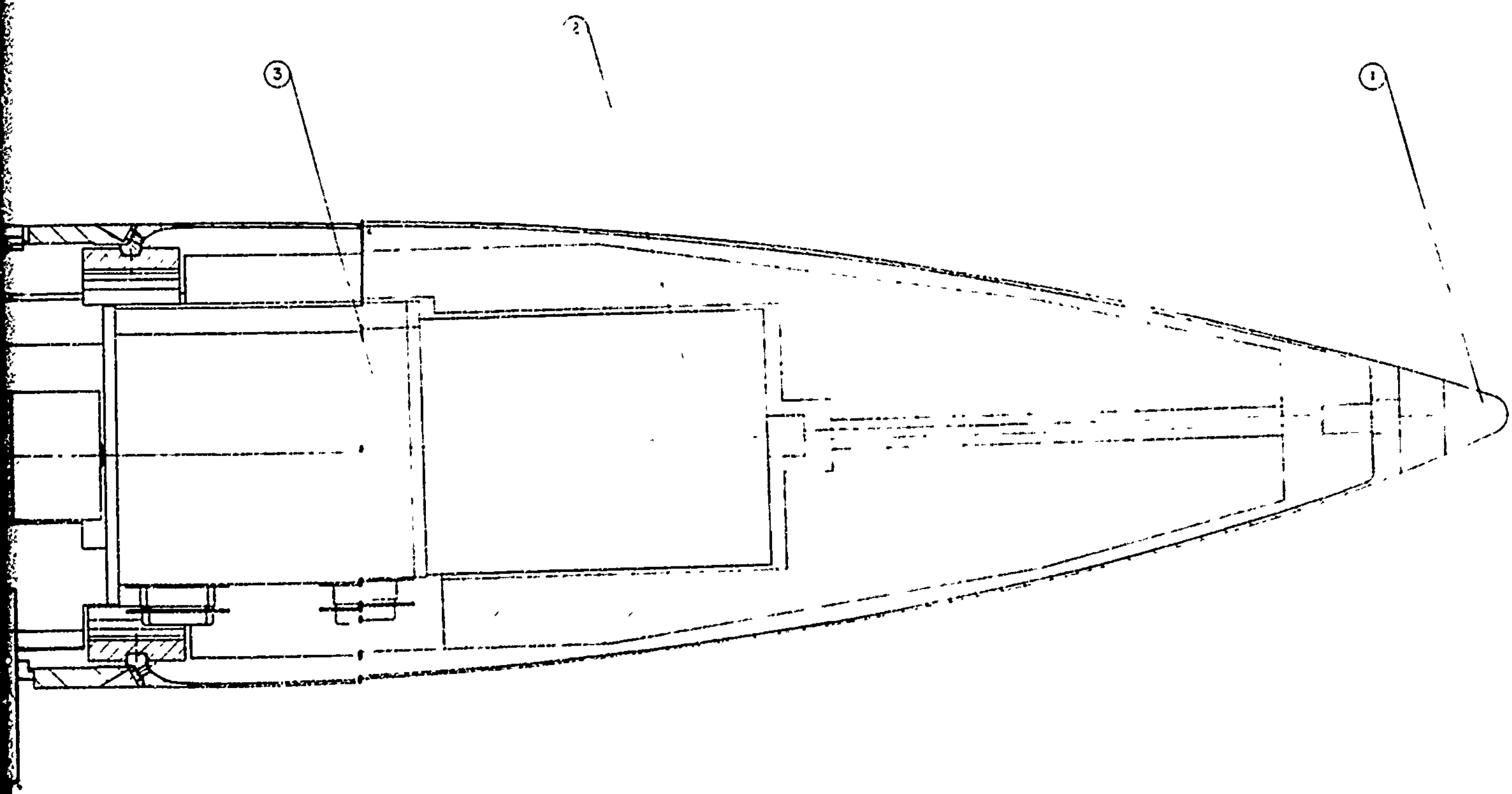
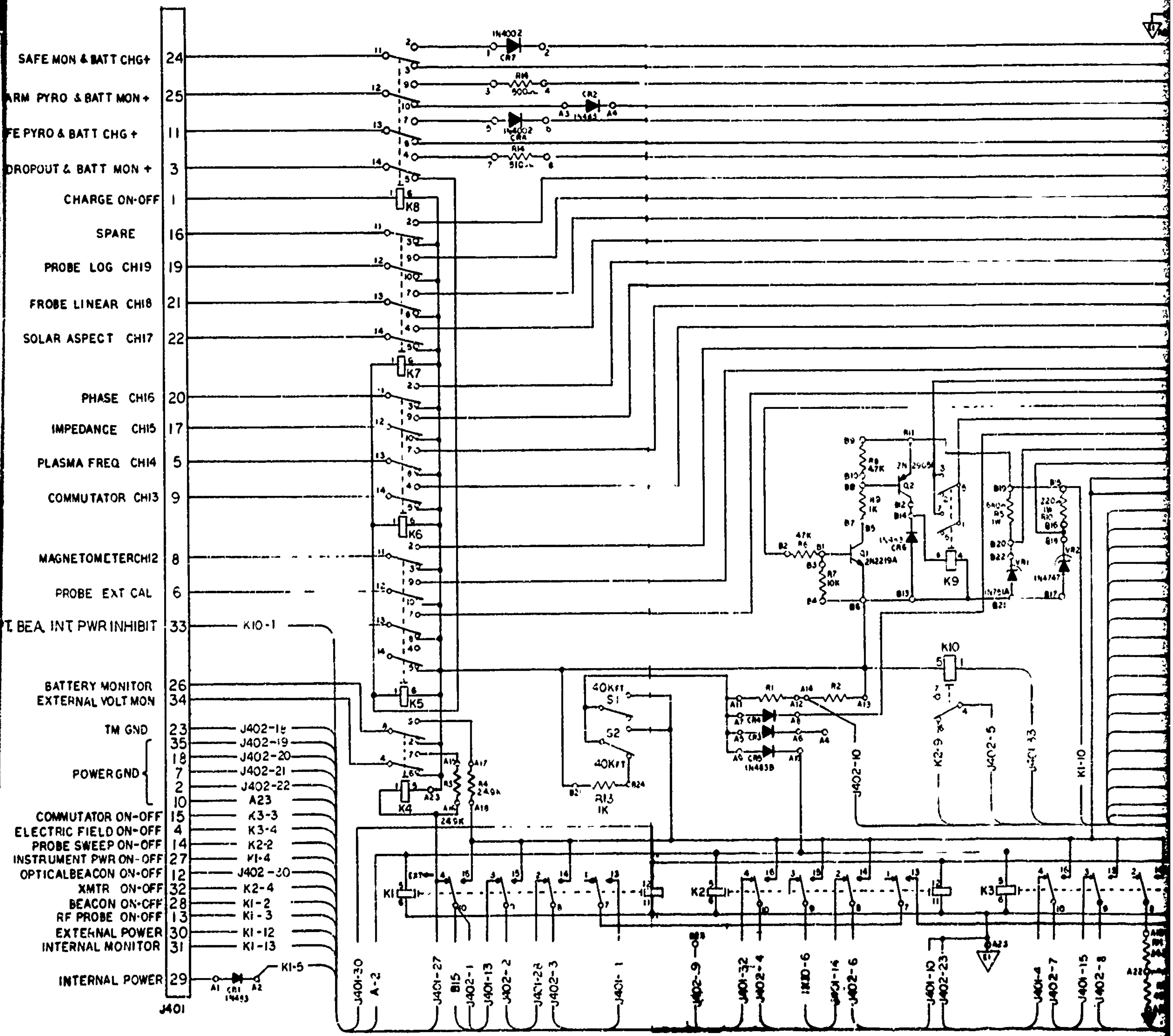


Figure 3. Main assembly drawing.

A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ARM PYRO & BATT MON+ 25
FE PYRO & BATT CHG+ 11
DROPOUT & BATT MON + 3
CHARGE ON-OFF 1
SPARE 16
PROBE LOG CH19 19
FROBE LINEAR CH18 21
SOLAR ASPECT CH17 22
PHASE CH16 20
IMPEDANCE CH15 17
PLASMA FREQ CH14 5
COMMUTATOR CH13 9
MAGNETOMETER CH12 8
PROBE EXT CAL 6
T. BEA. INT PWR INHIBIT 33
BATTERY MONITOR 26
EXTERNAL VOLT MON 34
TM GND 23
POWER GND 35 18 7 2 10
COMMUTATOR ON-OFF 15
ELECTRIC FIELD ON-OFF 4
PROBE SWEEP ON-OFF 14
INSTRUMENT PWR ON-OFF 27
OPTICAL BEACON ON-OFF 12
XMTR ON-OFF 32
BEACON ON-OFF 28
RF PROBE ON-OFF 13
EXTERNAL POWER 30
INTERNAL MONITOR 31
INTERNAL POWER 29
J401
K10-1
J402-19
J402-20
J402-21
J402-22
A23
K3-3
K3-4
K2-2
K1-4
J402-30
K2-4
K1-2
K1-3
K1-12
K1-13
K1-5
CR1
1N483
1N4002
CR7
CR2
CR4
R14
K8
K7
K6
K5
K4
K1
K2
K3
K9
K10
40K FT
S1
S2
R13
1K
2N2219A
2N2905
Q1
Q2
VR1
VR2
1N751A
1N4747
1N483B
J402-10
K2-9
J402-5
K1-10
J401-30
A-2
J401-27
B15
J402-1
J401-13
J402-2
J401-28
J402-3
J401-1
J402-9
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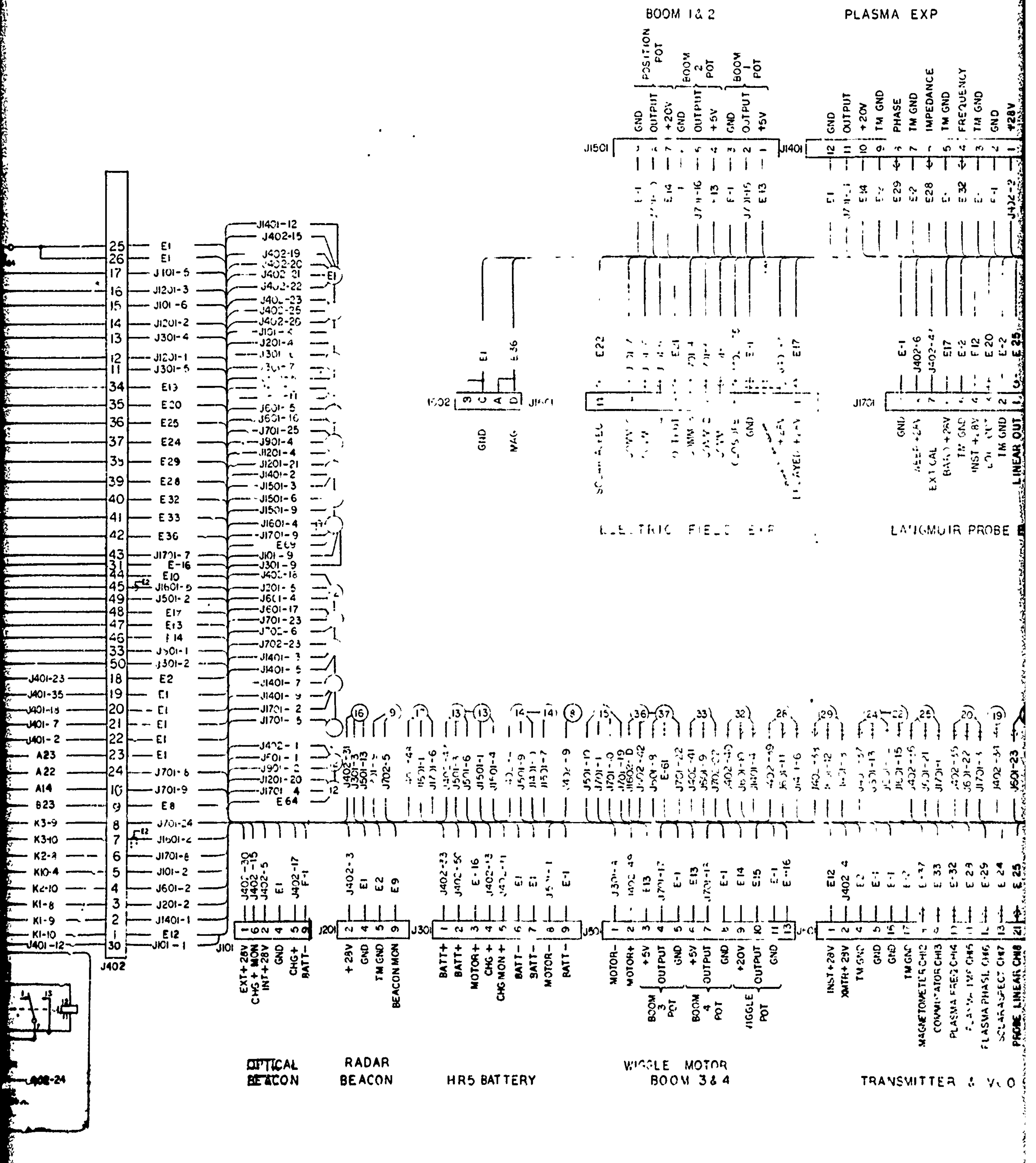
J402-23
J401-4
J402-7
J401-15
J402-8

B


BOOM 1 & 2
PLASMA EXP
POSITION POT
BOOM 2 POT
BOOM 1 POT
J1501
J1401
GND
OUTPUT
+20V
+5V
TM GND
PHASE
IMPEDANCE
FREQUENCY
+28V
J1602
J1601
MAG
J1701
LINEAR OUT
LANGMUIR PROBE
J402
J101
J201
J301
EXT+28V
CHG+ MON
INT+28V
CHG+
BATT-
BEACON MON
BATT+
MOTOR+
MOTOR-
CHG MON+
BOOM 3 POT
BOOM 4 POT
WIGGLE POT
INST+28V
XMTR+28V
MAGNETOMETER CH12
COMMUTATOR CH13
PLASMA FREQ CH14
PLASMA PHASE CH16
SOLAR ASPECT CH17
PROBE LINEAR CH18
OPTICAL BEACON
RADAR BEACON
HR5 BATTERY
WIGGLE MOTOR BOOM 3 & 4
TRANSMITTER & VCO

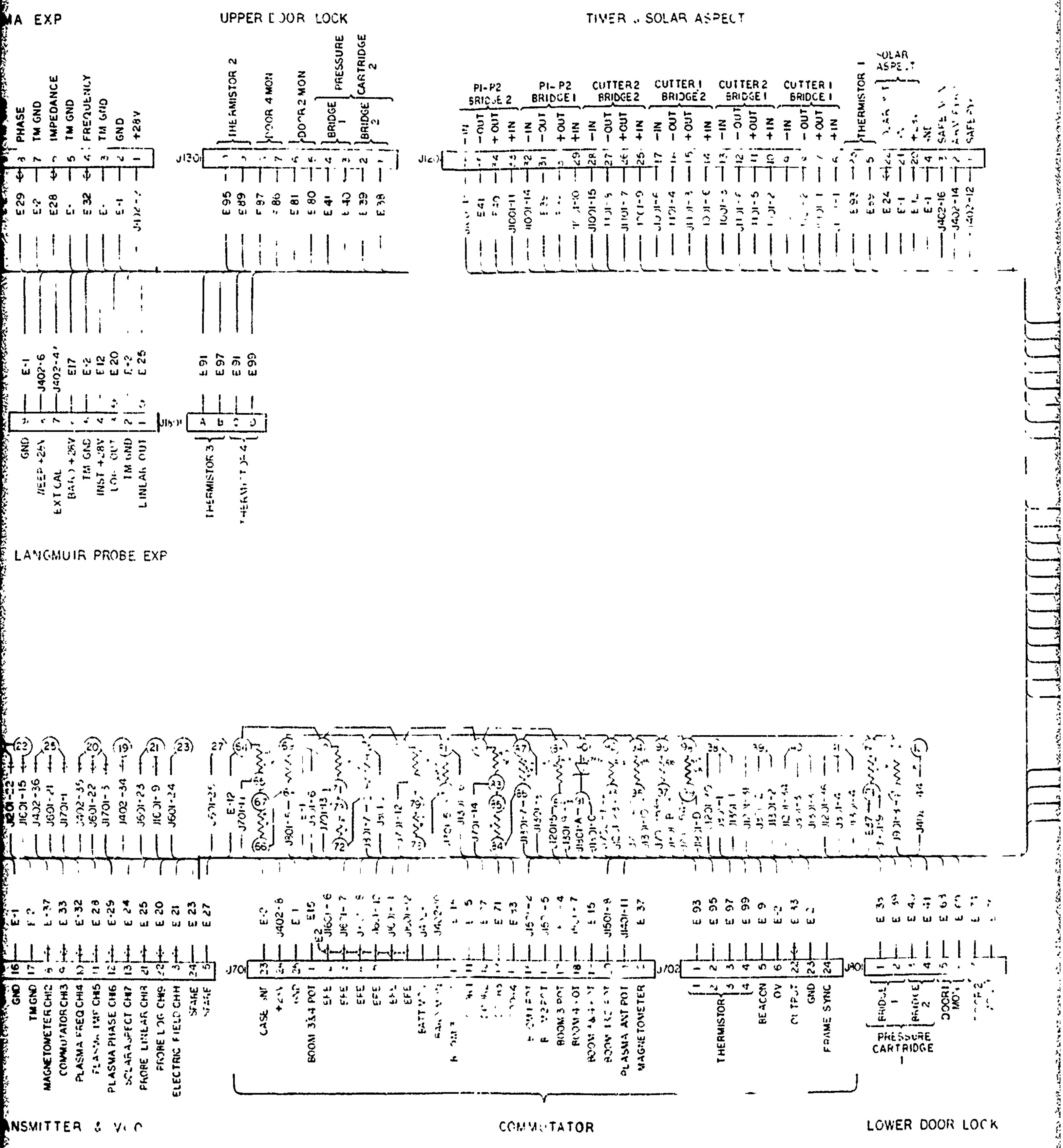


Figure 4. Rail wiring

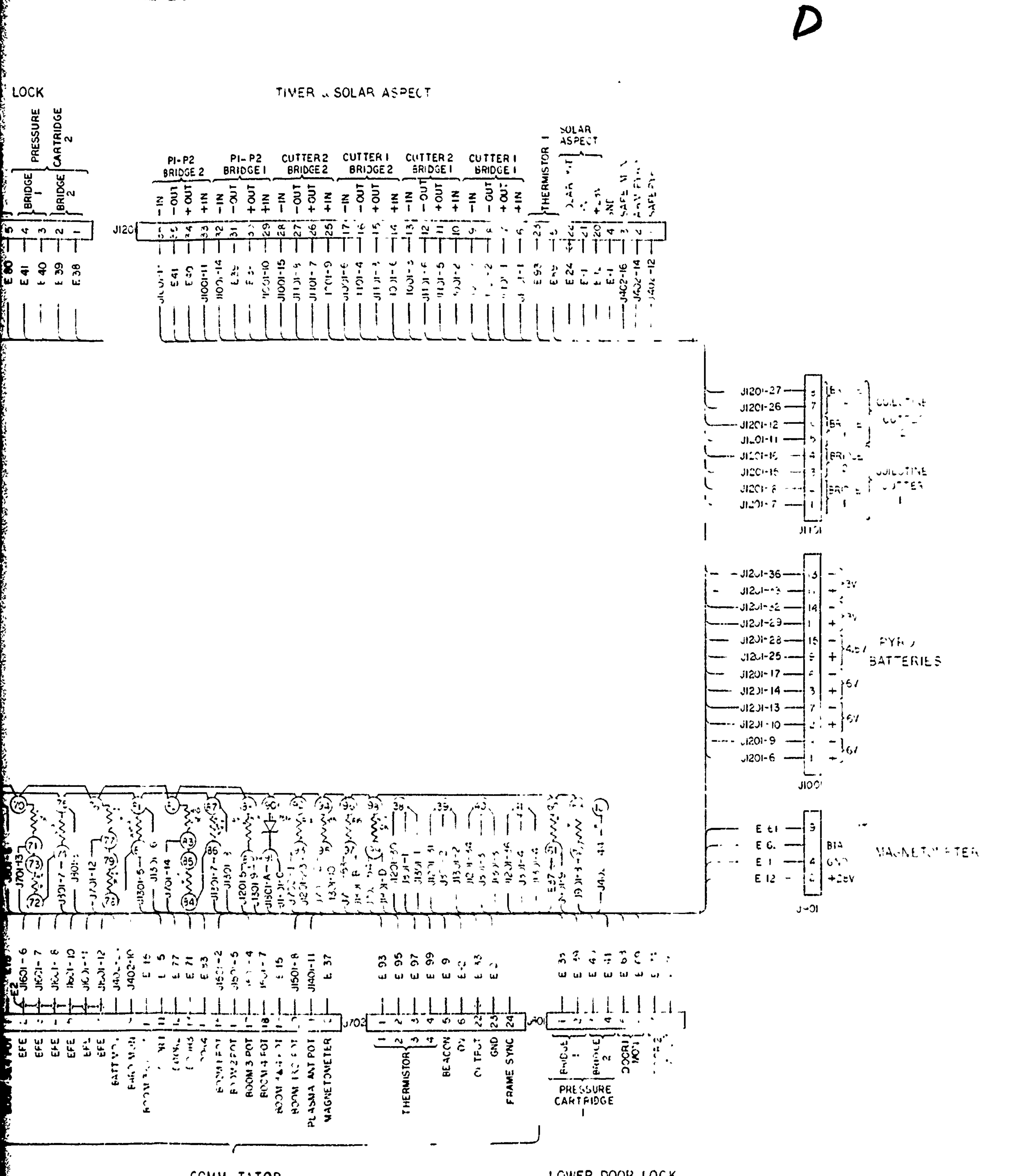


Figure 4. Rail wiring diagram.

TABLE 1

TELEMETRY CHANNEL ASSIGNMENTS

IRIG Channel	Freq. (Hz)	Nominal Intell. Freq. (Hz)	Signal
12	10.5	160	Magnetometer
13	14.5	220	Commutator
14	22.0	330	Plasma Resonance-Frequency
15	30.0	450	Plasma Resonance-Impedance
16	40.0	600	Plasma Resonance-Phase
17	52.5	790	Solar Sensor
18	70.0	1050	Langmuir Probe-Linear
19	93.0	1395	Langmuir Probe-Log
H	165.0	5000	Electric Field

TABLE 2

COMMUTATOR CHANNEL ASSIGNMENTS

Channel 1	Lower booms deployment potentiometer
2	EFE Monitor
3	EFE Monitor
4	EFE Monitor
5	EFE Monitor
6	EFE Monitor
7	EFE Monitor
8	Battery voltage monitor
9	Baro switch
10	Lower booms deployment potentiometer
11	Door 1 eject switch
12	Door 2 eject switch
13	Door 3 eject switch
14	Door 4 eject switch
15	Boom 1 extension
16	Boom 2 extension
17	Boom 3 extension
18	Boom 4 extension
19	Lower booms deployment potentiometer
20	Upper booms deployment potentiometer
21	Plasma resonance antenna deployment potentiometer
22	Spare
23	Thermistor-Timer & Solar Deck
24	Thermistor-Cylindrical Skin
25	Thermistor-Langmuir Probe Deck
26	Thermistor-Ogive
27	Spare
28	0 Volts
29	Frame Sync
30	Frame Sync

TABLE 3

COMPONENT PART AND SERIAL NUMBERS

Payload-Designation	E	A	Cert	B	C	D
Payload Serial #	1	2	3	4	5	6
Radar Beacon Vega 207C-1	184	185	188	186	187	183
Transmitter Conic CTP-402	402P056	402P060	402P059	402P058	402P057	402P055
Commutator Vector C5V-100	132	134	131	135	130	133
Magnetometer Schonstedt RAM 5C	2987	2980	2990	2988	2982	2989
Raymond Timer	13542	13544	13543	13545	135[illegible]1	13590
Solar Sensor	57	58	59	60	61	62
Plasma Resonance Box	70-3	70-6	70-4	70-1	70-2	70-5
Electric Field Box	2	1	7	4	5	6
Langmuir Probe Box	2	1	3	4	5	6

Table 4 gives the angles between each pair of booms and the optical axis of the solar aspect sensor. The angles are measured in the lateral plane of the payload. A positive value for an angle is representative of an angle measured from the subject optical axis in clockwise direction (and vice versa for negative values), when looking down onto the payload.

TABLE 4

ANGULAR CORRELATION

Payload No.	Solar Sensor-Lower Boompair	Solar Sensor-Upper Boompair
1	$+ 1.5'$	$- 90^\circ\ 2'$
2	$- 26'$	$- 90^\circ\ 12'$
3	$- 33'$	$- 89^\circ\ 32'$
4	$+ 7'$	$- 89^\circ\ 40'$
5	$+ 1^\circ\ 20'$	$- 88^\circ\ 29'$
6	$+ 26'$	$89^\circ\ 40'$

HeliFlux

MAGNETIC ASPECT SENSOR
TYPE RAM-5C

Serial No. 2987

CALIBRATION DATA

Field in Milligauss	Output Signal In Volts DC
600	4.81
550	4.61
500	4.41
450	4.21
400	4.01
350	3.80
300	3.60
250	3.40
200	3.20
150	3.00
100	2.79
50	2.59
0	2.39 (Bias Level)
-50	2.20
-100	2.00
-150	1.80
-200	1.59
-250	1.39
-300	1.19
-350	0.99
-400	0.79
-450	0.59
-500	0.39
-550	+0.19
-600	-0.01

Calibration made with battery supply of 28.0 volts. DATE 1-15-70

Figure 5a.

HeliFlux

MAGNETIC ASPECT SENSOR
TYPE RAM-5C

Serial No. 2980

CALIBRATION DATA

Field in Milligauss	Output Signal In Volts DC
600	4.79
550	4.59
500	4.39
450	4.20
400	3.99
350	3.79
300	3.59
250	3.39
200	3.19
150	2.99
100	2.79
50	2.59
0	2.40 (Bias Level)
-50	2.20
-100	2.00
-150	1.80
-200	1.60
-250	1.40
-300	1.20
-350	0.99
-400	0.79
-450	0.59
-500	0.39
-550	+0.19
-600	-0.01

Calibration made with battery supply of 28.0 volts. DATE 1-15-70

Figure 5b.

HeliFlux

MAGNETIC ASPECT SENSOR
TYPE RAM-5C

Serial No. 2990

CALIBRATION DATA

Field in Milligauss	Output Signal In Volts DC
600	4.79
550	4.59
500	4.39
450	4.19
400	3.99
350	3.80
300	3.60
250	3.40
200	3.19
150	3.00
100	2.80
50	2.60
0	2.40 (Bias Level)
-50	2.20
-100	2.00
-150	1.80
-200	1.60
-250	1.40
-300	1.19
-350	0.99
-400	0.78
-450	0.58
-500	0.38
-550	+0.18
-600	-0.02

Calibration made with battery supply of 28.0 volts. DATE 1-15-70

Figure 5c.

HeliFlux

MAGNETIC ASPECT SENSOR
TYPE RAM-5C

Serial No. 2988

CALIBRATION DATA

Field in Milligauss	Output Signal In Volts DC
600	4.80
550	4.61
500	4.41
450	4.21
400	4.01
350	3.81
300	3.61
250	3.41
200	3.20
150	3.00
100	2.80
50	2.60
0	2.40 (Bias Level)
-50	2.20
-100	2.00
-150	1.80
-200	1.60
-250	1.40
-300	1.19
-350	0.99
-400	0.79
-450	0.59
-500	0.39
-550	+0.19
-600	-0.00

Calibration made with battery supply of 28.0 volts. DATE 1-15-70

Figure 5d.

HeliFlux

MAGNETIC ASPECT SENSOR
TYPE RAM-5C

Serial No. 2982

CALIBRATION DATA

Field in Milligauss	Output Signal In Volts DC
600	4.80
550	4.61
500	4.41
450	4.22
400	4.02
350	3.82
300	3.62
250	3.42
200	3.21
150	3.01
100	2.81
50	2.61
0	2.40 (Bias Level)
-50	2.20
-100	2.00
-150	1.79
-200	1.59
-250	1.39
-300	1.18
-350	0.98
-400	0.78
-450	0.58
-500	0.38
-550	+0.18
-600	-0.02

Calibration made with battery supply of 28.0 volts. DATE 1-15-70

Figure 5c.

HeliFlux

MAGNETIC ASPECT SENSOR
TYPE RAM-5C

Serial No. 2989

CALIBRATION DATA

Field in Milligauss	Output Signal In Volts DC
600	4.79
550	4.60
500	4.40
450	4.20
400	4.00
350	3.80
300	3.60
250	3.40
200	3.20
150	3.00
100	2.80
50	2.60
0	2.40 (Bias Level)
-50	2.20
-100	2.00
-150	1.80
-200	1.60
-250	1.40
-300	1.19
-350	0.99
-400	0.79
-450	0.59
-500	0.39
-550	+0.19
-600	-0.01

Calibration made with battery supply of 28.0 volts. DATE 1-15-70

Figure 5f.

Elevation Angle	Azimuth Angle #57	#58	#59	#60	#61	#62
0^o	117.53	118.13	118.17	118.10	118.20	118.15
0^o	118.10	118.13	118.13	118.07	118.23	118.12
$+1^o$	118.07	118.12	118.12	118.03	118.15	118.02
$+2^o$	117.83	117.97	117.90	117.89	117.93	117.80
$+3^o$	117.40	117.52	117.43	117.43	117.47	117.45
$+4^o$	116.87	117.00	116.90	116.87	116.92	116.85
$+5^o$	116.18	116.33	116.17	116.30	116.40	116.22
$+5^o$	116.32	116.33	116.25	116.25	116.47	116.12
$+10^o$	112.92	113.05	113.08	112.97	113.18	112.98
$+15^o$	109.58	109.72	109.87	109.58	109.80	109.58
$+20^o$	105.98	105.28	106.22	106.22	106.28	106.08
$+25^o$	102.28	102.65	102.43	102.32	102.47	102.37
$+30^o$	98.15	98.57	98.28	98.32	98.57	98.47
0^o	118.15	118.23	118.25	118.15	118.30	118.13
0^o	118.17	118.23	118.22	118.20	118.33	118.18
-1^o	119.33	118.23	118.17	118.17	118.28	118.18
-2^o	119.37	117.92	117.97	117.95	118.13	117.97
-3^o	119.48	117.47	117.53	117.50	117.78	117.63
-4^o	116.93	116.90	117.00	116.93	117.28	117.07
-5^o	116.40	116.30	116.33	116.32	116.72	116.55
-5^o	116.35	116.20	116.57	116.23	116.67	116.50
-10^o	113.17	112.98	113.18	113.17	113.43	113.20
-15^o	109.92	109.72	109.87	109.75	110.10	109.92
-20^o	106.47	106.30	106.50	107.02	--	--

Figure 6. Solar aspect sensor calibration.

TABLE 5

POWER CONSUMPTION

	Power Consumption At 28 V DC (mA)
Optical Beacon	10×10^3
Radar Transponder	1×10^3
Control Deck	150
Transmitter	1×10^3
VCO's	100
Wobble Motor	7×10^3
Magnetometer	22
Commutator	50
Solar Aspect & Timer Deck	120
EFE	1×10^3
Plasma Resonance	350
Langmuir Probe	250

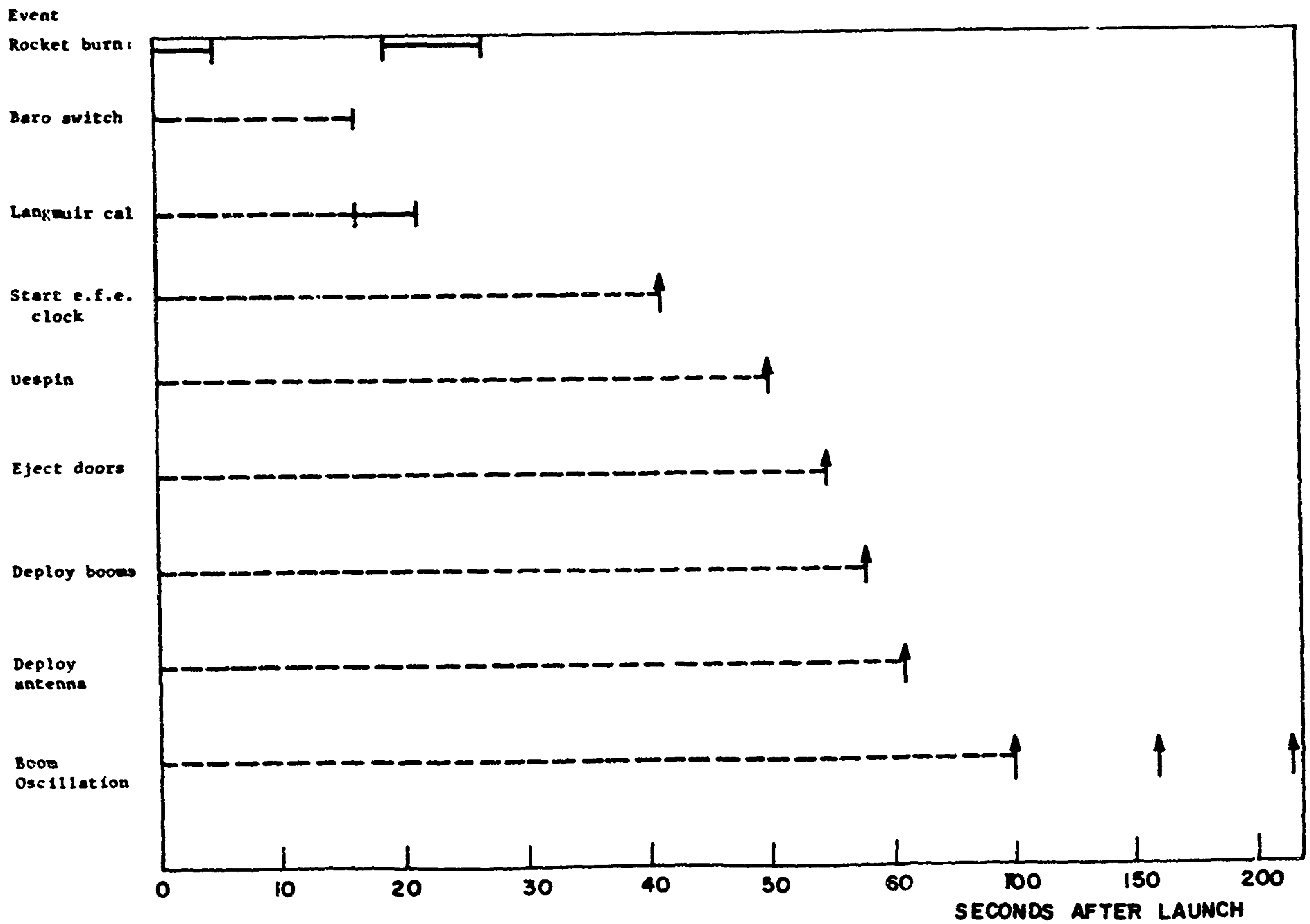


Figure 7. Timing diagram of the various functions.

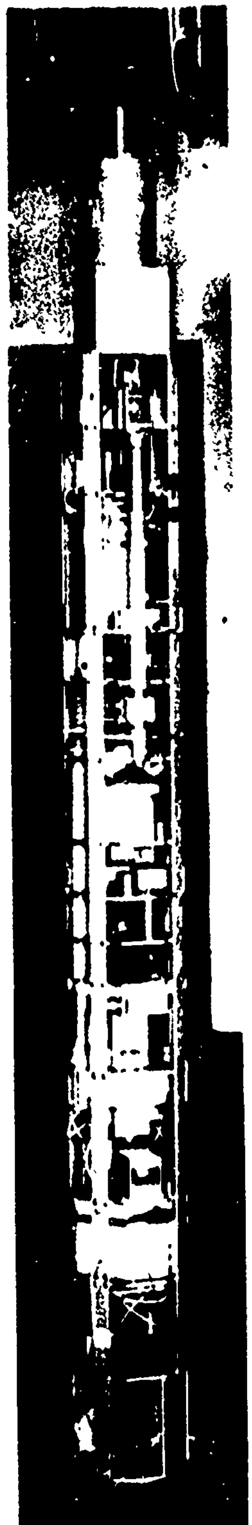


Figure 8. Rack assembly.

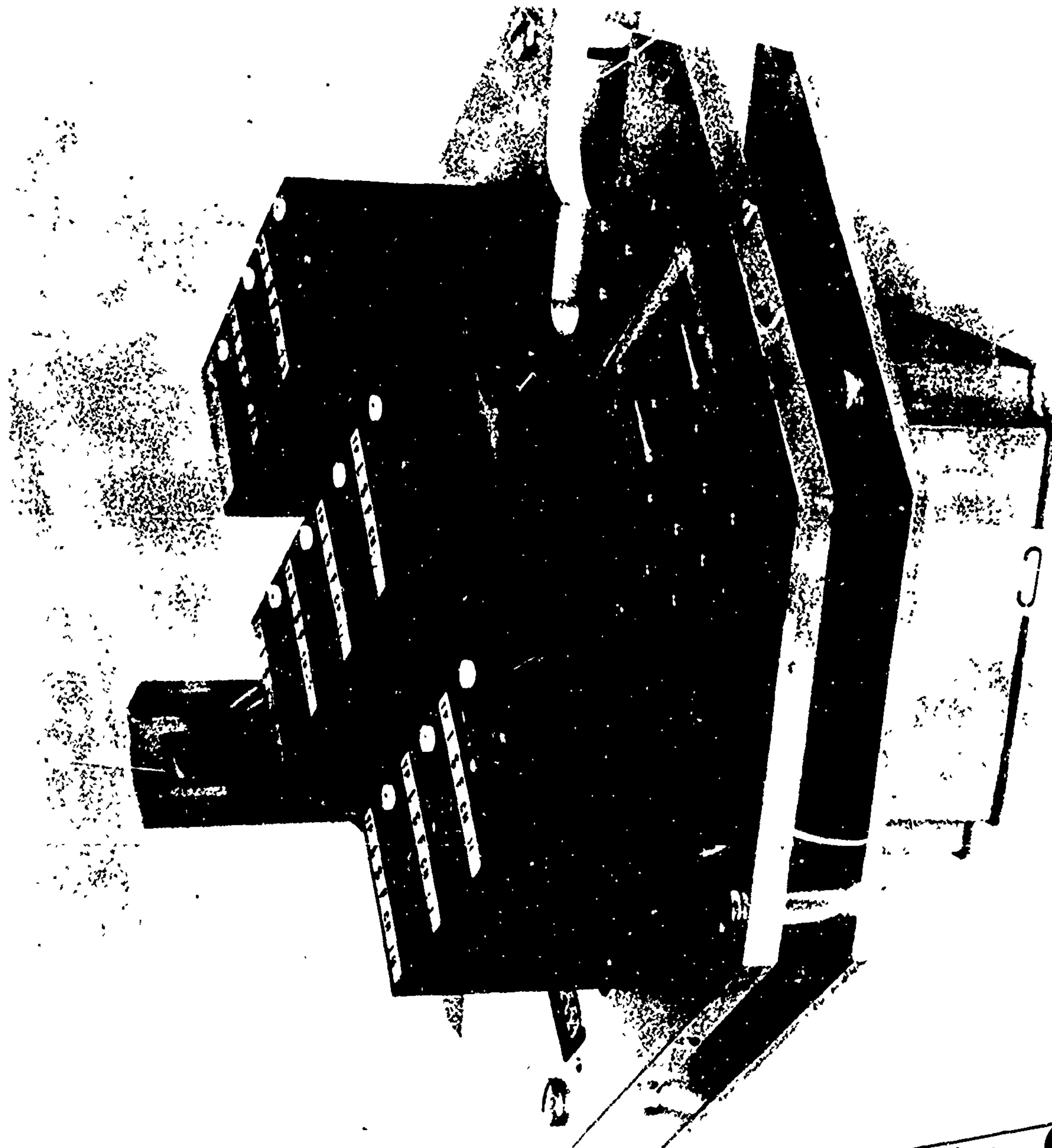


Figure 9. VCO/transmitter assembly.

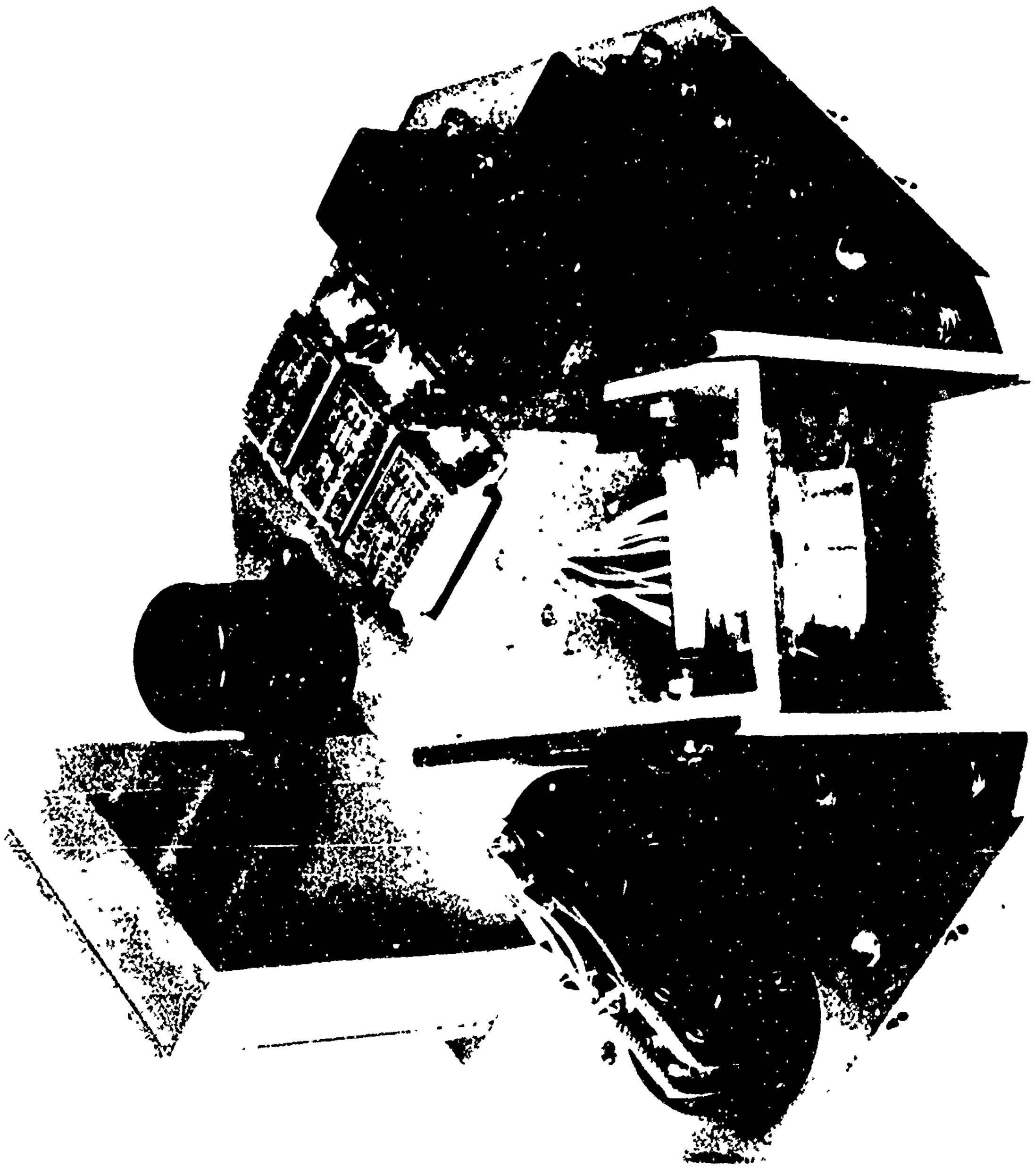
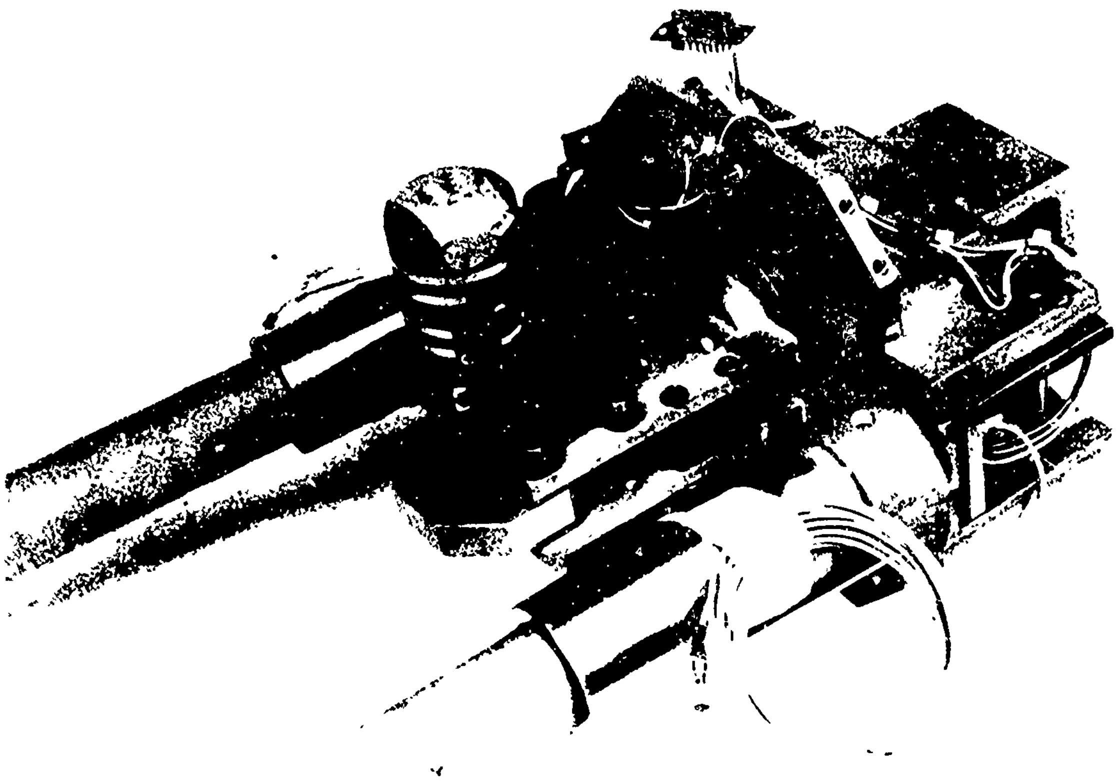


Figure 10. Control deck.



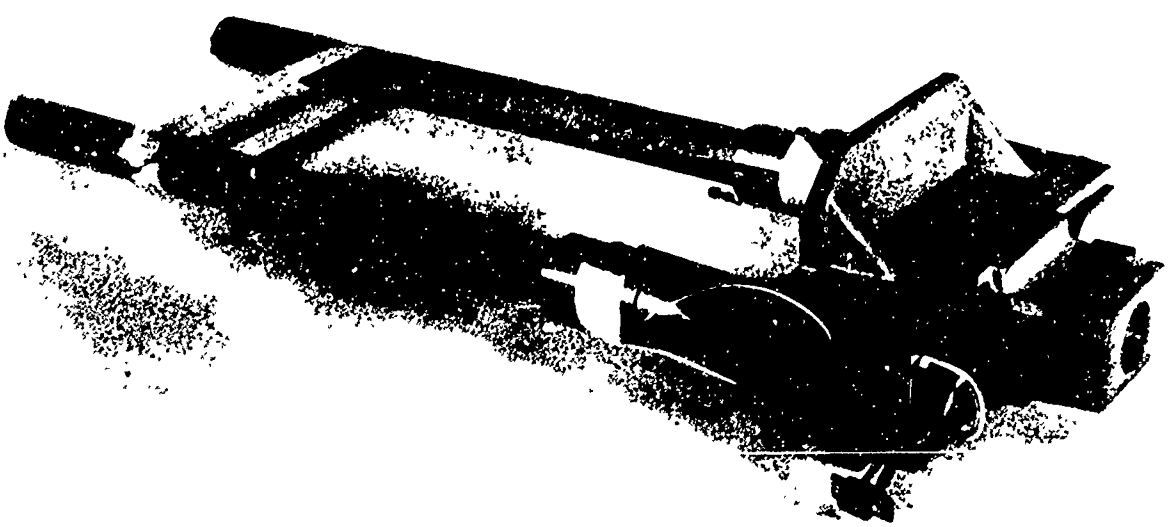
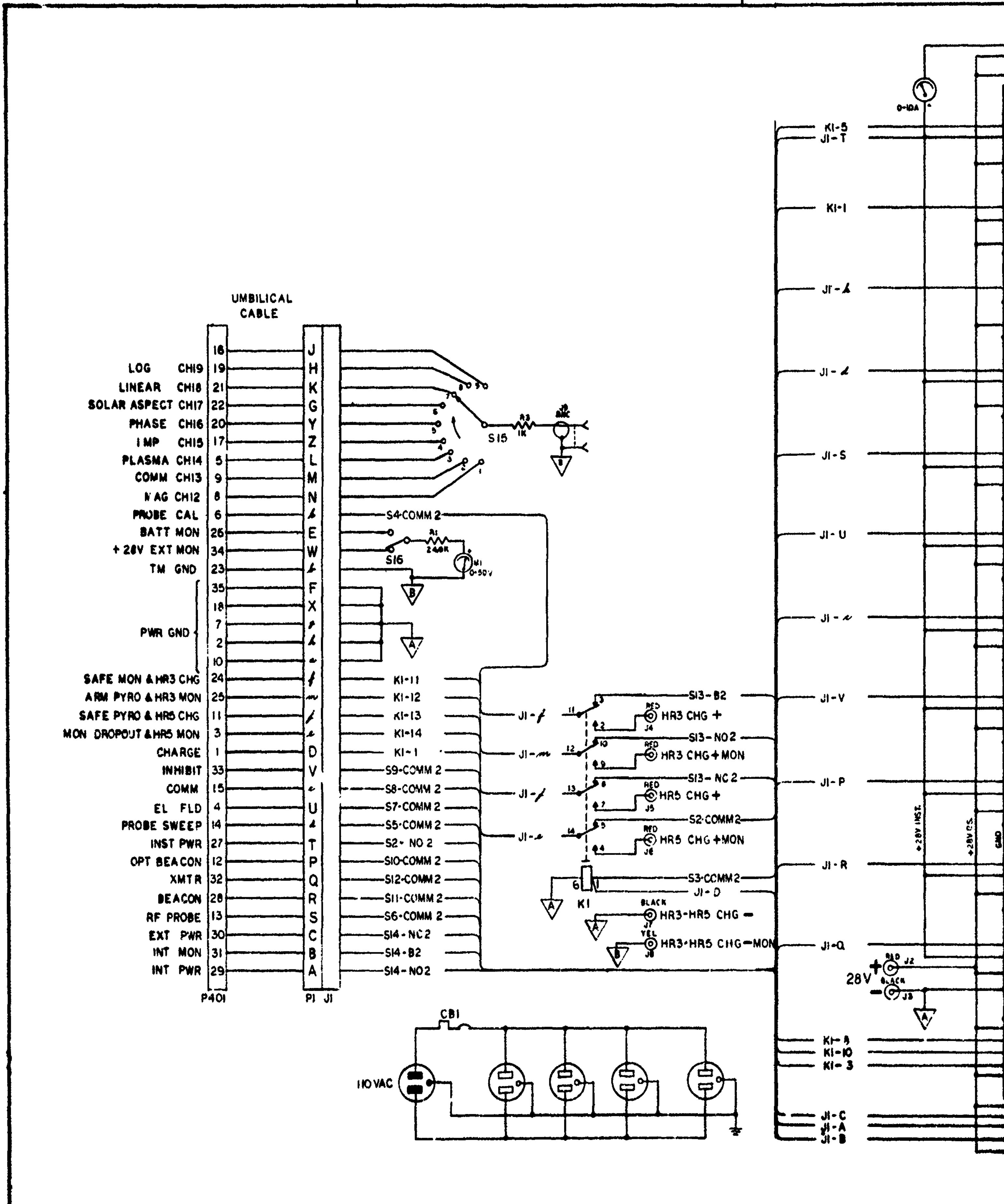


Figure 11. Boom assembly.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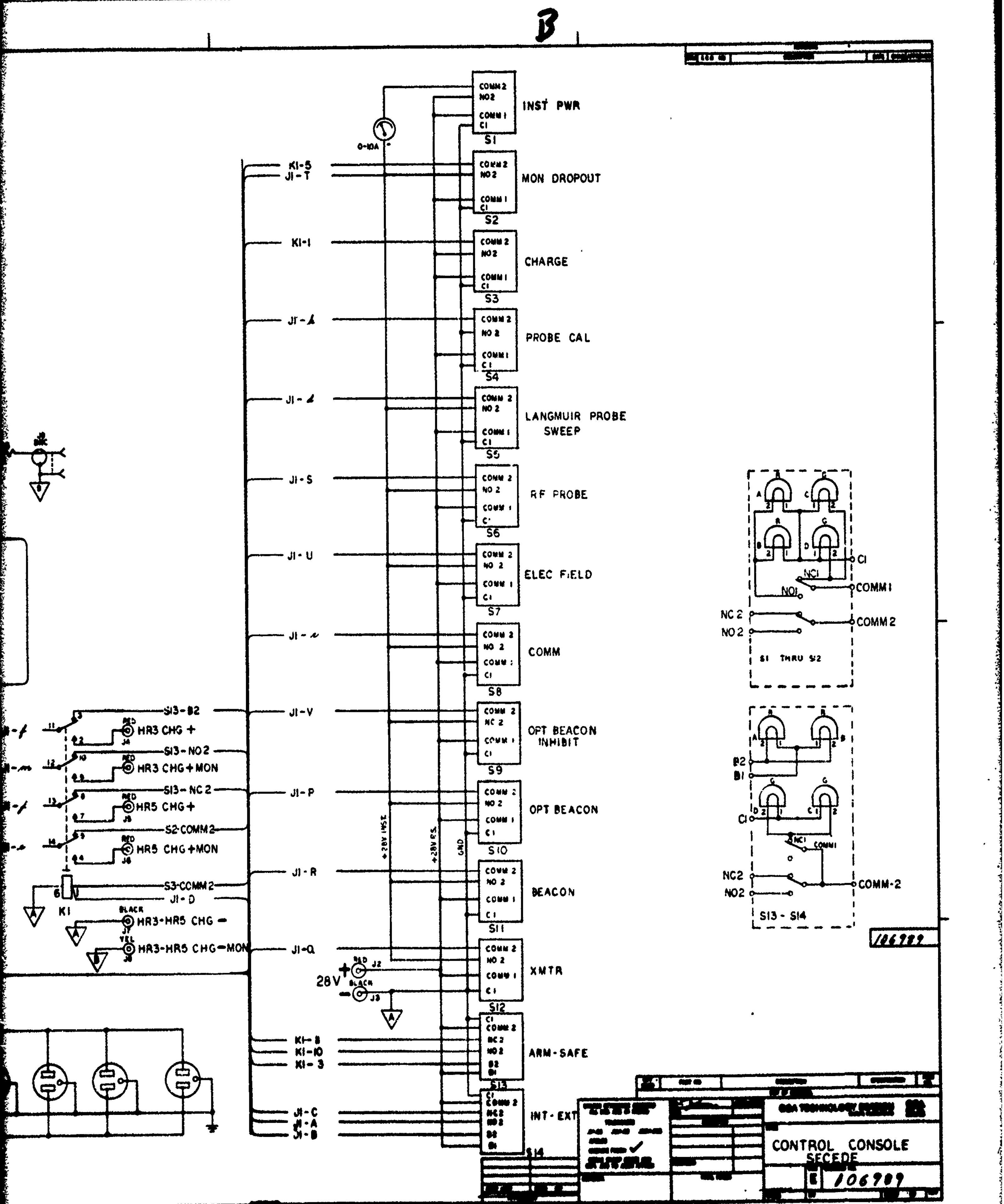
LOG CH19
LINEAR CH18
SOLAR ASPECT CH17
PHASE CH16
IMP CH15
PLASMA CH14
COMM CH13
MAG CH12
PROBE CAL
BATT MON
+28V EXT MON
TM GND
PWR GND
SAFE MON & HR3 CHG
ARM PYRO & HR3 MON
SAFE PYRO & HR5 CHG
MON DROPOUT & HR5 MON
CHARGE
INHIBIT
COMM
EL FLD
PROBE SWEEP
INST PWR
OPT BEACON
XMTR
BEACON
RF PROBE
EXT PWR
INT MON
INT PWR
P401
P1
J1
S15
S16
S4-COMM 2
K1-11
K1-12
K1-13
K1-14
K1-1
S9-COMM 2
S8-COMM 2
S7-COMM 2
S5-COMM 2
S2-NO 2
S10-COMM 2
S12-COMM 2
S11-COMM 2
S6-COMM 2
S14-NC 2
S14-B2
S14-NO2
S13-B2
HR3 CHG +
S13-NO2
HR3 CHG+MON
S13-NC 2
HR5 CHG +
S2-COMM2
HR5 CHG +MON
S3-COMM2
J1-D
K1
HR3-HR5 CHG −
HR3-HR5 CHG−MON
CB1
110VAC
0-10A
K1-5
J1-T
K1-1
J1-S
J1-U
J1-V
J1-P
J1-R
J1-Q
28V
K1-8
K1-10
K1-3
J1-C
J1-A
J1-B
+28V INST.
+28V C.S.
GND
0-50V



B
COMM 2
NO 2
COMM 1
C1
INST PWR
S1
0-10A
K1-5
J1-T
MON DROPOUT
S2
K1-1
CHARGE
S3
PROBE CAL
S4
LANGMUIR PROBE SWEEP
S5
J1-S
RF PROBE
S6
J1-U
ELEC FIELD
S7
COMM
S8
J1-V
OPT BEACON INHIBIT
S9
J1-P
OPT BEACON
S10
J1-R
BEACON
S11
J1-Q
XMTR
S12
ARM-SAFE
K1-8
K1-10
K1-3
S13
J1-C
J1-A
J1-B
INT-EXT
S14
+28V INST
+28V R.S.
GND
28V
J2
J3
RED
BLACK
S13-B2
HR3 CHG +
J4
S13-NO2
HR3 CHG+MON
S13-NC2
HR5 CHG+
J5
S2-COMM2
HR5 CHG+MON
J6
S3-COMM2
J1-D
K1
HR3-HR5 CHG −
J7
HR3-HR5 CHG−MON
J8
C1
COMM 1
NC1
NO1
NC 2
NO 2
COMM 2
S1 THRU S12
B2
B1
COMM-2
S13 - S14
106989
CONTROL CONSOLE
SECEDE
E
106989

Figure 12.

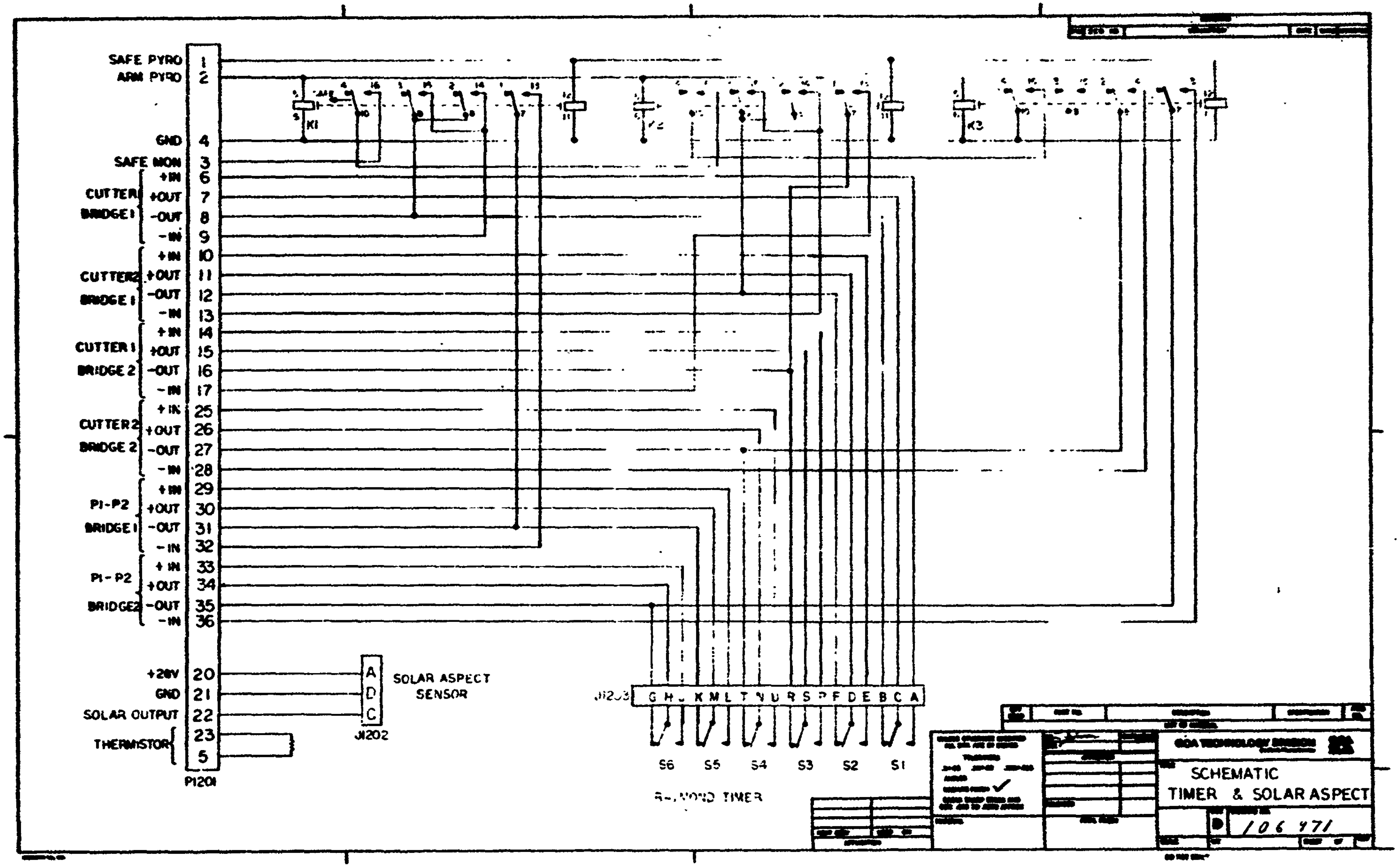

SAFE PYRO
ARM PYRO
GND
SAFE MON
CUTTER1 BRIDGE1
CUTTER2 BRIDGE1
CUTTER1 BRIDGE2
CUTTER2 BRIDGE2
P1-P2 BRIDGE1
P1-P2 BRIDGE2
+IN
+OUT
-OUT
-IN
+28V
GND
SOLAR OUTPUT
THERMISTOR
P1201
K1
K2
K3
SOLAR ASPECT SENSOR
J1202
J1203
S6
S5
S4
S3
S2
S1
SCHEMATIC
TIMER & SOLAR ASPECT
106 471

Figure 13

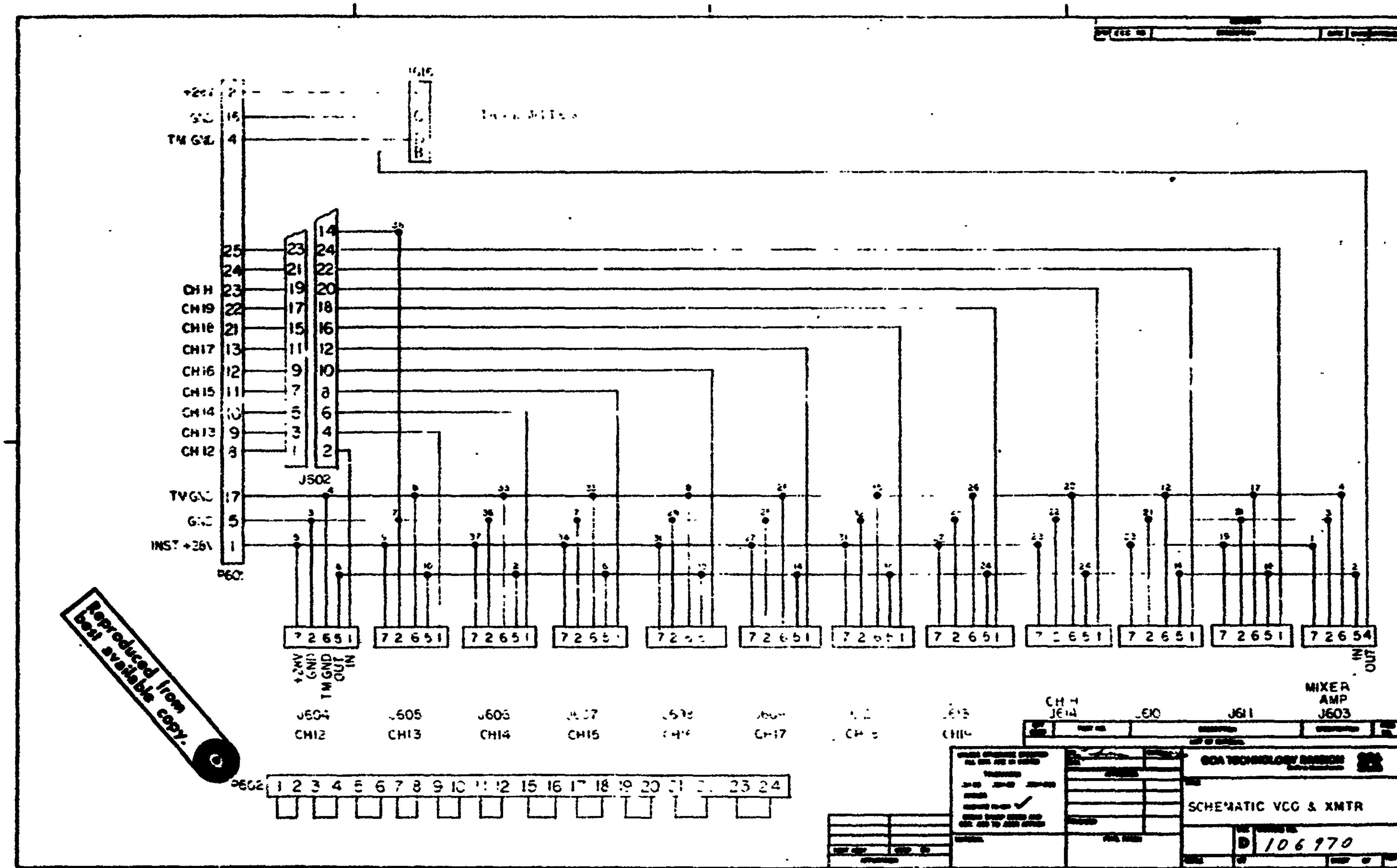

TM GND
CH12
CH13
CH14
CH15
CH16
CH17
CH18
CH19
TV GND
INST +26V
P602
J502
+26V
GND
TM GND
OUT
IN
J604
CH12
J605
CH13
J606
CH14
CH15
CH17
CH14
J614
J610
J611
MIXER
AMP
J603
P602
SCHEMATIC VCO & XMTR
D 106970

Figure 14

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